

By order of the College, this Book is not to be taken out of the Library (except after 6 P.M. *until* 10 A.M.*) for one month from this date.*

PHYSICIANS' HALL, 14 Aug 1911

2 Vols

*Fa 6.26

R36324

A

MANUAL OF PALÆONTOLOGY

A

MANUAL OF PALÆONTOLOGY

FOR THE USE OF STUDENTS

WITH A GENERAL INTRODUCTION ON THE PRINCIPLES OF PALÆONTOLOGY

BY

HENRY ALLEYNE NICHOLSON

M.D., D.Sc., F.G.S., ETC.

REGIUS PROFESSOR OF NATURAL HISTORY IN THE UNIVERSITY OF ABERDEEN

AND

RICHARD LYDEKKER

B.A., F.G.S., ETC.

ROYAL COLLEGE OF PHYSICIANS, EDINA LIBRARY

THIRD EDITION

REWRITTEN AND GREATLY ENLARGED

IN TWO VOLUMES

VOL. I.

WILLIAM BLACKWOOD AND SONS

EDINBURGH AND LONDON

MDCCCLXXXIX

All Rights reserved

PREFACE.

THERE is, perhaps, no branch of Biology which in recent years has advanced so rapidly, and, on the whole, so surely and in so many directions, as has Palæontology. In the earlier periods of its development, a tendency has, indeed, been sometimes shown by investigators concerned exclusively with existing forms of life to depreciate the position of Palæontology as a Science, and to contest its claims to recognition as a separate department of Zoology and Botany; nor can it be said that this tendency has yet altogether died out. Even now, it is sometimes considered that Palæontology, on the ground of its relation to the chronological history of the earth, should be regarded as a branch of Geology, rather than of Biology; while on the ground of its being necessarily concerned almost wholly with the skeletal structures of animals and plants, its conclusions have been discredited, and the adequacy of its methods of investigation has been questioned.

No one, however, who has made himself thoroughly acquainted with the progress of this branch of investigation during the last decade, can doubt that Palæontology has amply vindicated its claim to be regarded as a special department of Biology, as entirely scientific in its character and methods, and in all respects as worthy of separate and special study as is, for example, the department of Embryology.

So numerous and so extensive have been the advances made by Palæontology of late years, that the Authors have found it necessary not only to largely increase the bulk of the present, as compared with the last, edition of this work; but also to entirely recast and rewrite it, while the illustrations to the text have been nearly

doubled in number. The present edition may therefore be considered as, to all intents and purposes, an entirely new work. The Authors also trust that this edition will be found to have gained much from the fact that the Invertebrates and Vertebrates have been dealt with by different writers.

With regard to the general plan of the work, the Authors need only say that the Invertebrate and Vertebrate animals have been treated of as fully as considerations of space would permit; while the fossil plants have been dealt with in a comparatively summary fashion. This course has been followed primarily on the ground that Palæozoology is of much greater importance to the general student than is Palæobotany; but it has been also dictated by the consideration that the latter subject is one of great complexity, and is at the same time one upon which neither of the Authors has any claim to speak with authority. It did not seem advisable, however, to entirely omit the subject of Palæobotany; and an attempt has accordingly been made to give such a general summary of the present condition of our knowledge of this department as may be found useful to those studying Palæontology as a whole.

In dealing with the vast mass of facts constituting the modern science of Palæontology, much has been, necessarily, omitted; while the Authors can scarcely hope that errors have been altogether avoided. Moreover, in its present condition of rapid growth and development, Palæontology presents many questions—sometimes affecting points of fundamental importance—upon which the opinions of different investigators are widely divergent. It is, therefore, inevitable that there should be many questions dealt with in the present work in regard to which the opinions expressed by the Authors differ from those held by other workers in the same field. The Authors can only hope that on such controverted points they have not expressed themselves too dogmatically; and that, while the limits and scope of the work would not admit of any detailed discussion of divergent views, the existence of such has nevertheless been generally indicated. It may be added that where a definite position has been taken up upon a controverted question, this has been, in general, the result of original investigation on the part of the writer. Theoretical questions, again, have been for the most part avoided, partly because of their unsuitability for discussion in a work intended for students, and partly also from want of

space. Finally, the minute structure of the skeleton in different groups of animals, and particularly in the lower types, has been treated of as fully as the limits of the work have allowed.

Owing to the circumstance that a large portion of the first volume of this work has been in type for a considerable time, the Authors regret that they have not been able to avail themselves fully, or at all, of some recent publications, of both a general and a special nature, such, for example, as Neumayr's 'Die Stämme des Thierreichs,' and the newly published volume of Barrande's monumental work dealing with the Cystideans. In an Appendix to the second volume attention is, however, directed to certain points of importance which have emerged during the passage of this work through the press. Such errors as have been recognised will be found in a list of Corrigenda at the end of the Table of Contents to each volume.

To many of their fellow-workers the Authors have to express their obligation for direct or indirect assistance in their task. To no one is this more largely due than to Professor Karl von Zittel, to whose masterly 'Handbuch der Palæontologie' they have been on many occasions indebted for guidance in questions of doubt or difficulty. The very special gratitude of the Authors is due to Dr P. Herbert Carpenter for the most valuable assistance in the preparation of the chapters dealing with the Echinoderms, as also to Mr A. Smith Woodward and Dr R. H. Traquair for much information concerning fossil Fishes. They have likewise to express their best thanks to Dr George J. Hinde, Dr H. B. Brady, Dr Henry Woodward, Professor T. Rupert Jones, Mr A. H. Foord, Mr John Young, and others of their fellow-workers, from whom they have received much friendly help. Finally, the Authors have to express their gratitude to those who have assisted them by allowing them the use of illustrations. Amongst those to whom thanks are due on this score are M. Louis Dollo, Professors H. F. Osborne and W. B. Scott, Professor A. Gaudry, Professor E. D. Cope, Professor O. C. Marsh, Professor E. Koken, Dr Anton Fritsch, Dr Henry Woodward, the Director of British Museum (Natural History), the present and late Directors of the Geological Survey of India, and the Director of the Geological Survey of Canada.

CONTENTS OF THE FIRST VOLUME.

PART I.—GENERAL INTRODUCTION.

CHAPTER I.

PAGE

Definition of Palæontology—Palæozoology and Palæobotany—Definition of the term "fossil"—Processes of fossilisation—Definition of Rock—Classification of rocks, ... 3-10

CHAPTER II.

Characters of the Sedimentary rocks — Mode of formation of the Sedimentary rocks—General use of the term "formation"—Chief divisions of the Aqueous rocks—Mechanically-formed rocks—Chemically-formed rocks—Rock-salt—Gypsum—Phosphate of lime—The mode of origin of the Calcareous rocks generally—Organic origin of many limestones — Chief varieties of the organic limestones—Secondary crystallisation in limestones—Fibro-crystalline structure in limestones—Summary of the chief groups of organisms concerned in the formation of limestones—Sorby's researches on aragonite and calcite—Chemical composition of the skeleton of calcareous organisms—Preservation of calcareous organisms in limestones—Lithological characters of different limestones—Magnesian limestones—Oolitic structure of limestones—Superinduced crystallisation in limestones—Metamorphic limestones — Siliceous organic deposits — Beds of Sponge spicules—Flint and chert—Deposits of silicates—Carbonaceous deposits, ... 11-35

CHAPTER III.

Different ages of the Aqueous rocks as determined by stratigraphical and palæontological evidence—General chronological succession of the Aqueous rocks—Definition of names of rock-groups—General classification of the Post-Archæan fossiliferous

deposits—The value and nature of palæontological evidence in stratigraphical geology—Relative value of different groups of organisms as tests of the age of strata—Contemporaneity and homotaxis—General sequence of phenomena at the close of each geological period—Migrations—Differences between the organic remains of known contemporaneous deposits—Geological continuity—Stratigraphical breaks and their general causes—Life-zones—The doctrine of "colonies," 36-62

CHAPTER IV.

Causes of the imperfection of the palæontological record—Causes of the absence of certain animals as fossils—Unrepresented time—Geological breaks—Sequence of phenomena indicated by unconformity—Thinning-out of beds—Deep-sea deposits, and their supposed absence from the stratified series—Disappearance of fossils, ... 63-76

CHAPTER V.

Conclusions to be drawn from fossils—Age of rocks—Mode of origin of any fossiliferous bed—Fluviatile, lacustrine, and marine deposits—Conclusions as to climate—Existence of climatic zones in past time, ... 77-81

CHAPTER VI.

Relations of Palæontology to Geology—Relations of Palæontology to Zoology and Botany—Methods of palæontological investigation—Correlation of organs—Classification of the Animal Kingdom—Primary morphological types—Impossibility of a linear classification—The term "species" in Palæontology—Tabular view of the divisions of the Animal Kingdom, ... 82-95

CHAPTER VII.

The evolution of organic types in time—Earlier theories on the subject—The primordial types of life—The introduction of new species—The abrupt appearance of new species—The relative persistence of species in time—The relative range of morphological types in space—The extinction of morphological types—The evolution of morphological types from pre-existing forms—Comprehensive types—Generalised character of many fossil animals—Embryonal types—General palæontological evidence in favour of the evolution of species from pre-existing species—General progression of organic types—The absence of closely-graduated transitional forms between allied morphological types, ... 96-105

PART II.—PALÆOZOOLOGY.

INVERTEBRATA.

CHAPTER VIII.

Zoological characters and chief divisions of the Protozoa—The palæontological history of the Protozoa—The general characters of the Foraminifera—Variations in the structure of the test in the Foraminifera—The form of the Foraminiferal test and its variations—Distribution of the Foraminifera in space—Distribution of the Foraminifera in time—Classification of the Foraminifera—The general characters and distribution in time of the families of the Foraminifera—Appendix on Eozoön Canadense, 109-143

CHAPTER IX.

The general zoological characters of the Radiolaria—The skeleton of the Radiolarians and its chief variations as regards chemical composition and form—Classification of the Radiolarians—Distribution of the Radiolarians in space—Distribution of the Radiolarians in time—Literature of the Protozoa, . . 144-150

CHAPTER X.

General zoological characters of the Porifera—Canal-system of Sponges—General structure of the skeleton and its variations in Sponges—Distribution of Sponges in space—Different modes in which the skeleton of Sponges may be preserved in the fossil condition—General geological distribution of Sponges, . 151-159

CHAPTER XI.

Classification of Sponges—Class Plethospongiæ—Order Myxospongiæ—Ceratospongiæ—Characters and geological distribution of the Monactinellidæ—Tetractinellidæ—Lithistidæ—Hexactinellidæ—Groups and geological distribution of Hexactinellids—Octactinellidæ—Heteractinellidæ—Class Calcispongiæ—Homocœla—Heterocœla—Syconidæ—Leuconidæ—Pharetrones—Literature, ... 160-182

CHAPTER XII.

Groups of doubtful affinities—Archæocyathinæ—Archæocyathus—Ethmophyllum—Pasceolus—Cyclocrinus—Nidulites—Literature, ... 183-189

CHAPTER XIII.

General characters and divisions of the Cœlenterata—General distribution of Cœlenterates in time—General characters of the Hydrozoa—Distribution of the Hydrozoa in time—The Hydroid Zoophytes—Corynida—Hydractinia—Parkeria—Mitcheldeania—Solenopora—Thecaphora—Dendrograptus—Dictyonema—Oldhamia—Trachymedusæ—The Lucernarians—Acraspedote Jelly-fishes—Eophyton, ... 190-209

CHAPTER XIV.

General characters of the Graptolitoidea—Development—Morphology of a simple Graptolite—Reproduction of Graptolites—Leading types of structure among the Graptolites—Corynoides—Monograptidæ—Leptograptidæ—Dichograptidæ—Dicranograptidæ—Diplograptidæ—Lasiograptidæ—Retiolitidæ—Phyllograptidæ—Distribution of the families of Graptolites in time—Zoological relationships of the Graptolites, ... 210-222

CHAPTER XV.

General characters of the Hydrocorallines—Structure of Millepora—Geological distribution of the Milleporoids—General characters of the Stylasteridæ—Structure of Allopora—Distribution of the Stylasteridæ in time—The Syringosphæridæ—General characters of the Stromatoporoids—Structure of the skeleton—Chief types of the Stromatoporoids—Actinostroma—Labechia—Beatricea—Stromatopora—Amphiphora and Idiostroma—"Caunopora"—Zoological relationships of the Stromatoporoids—General distribution of the Stromatoporoids in time—Literature of the Hydrozoa, ... 223-239

CHAPTER XVI.

General characters of the Actinozoa—Structure of the soft parts of a simple Actinozoön—Development of the mesenteries—The nature of the skeleton in the Actinozoa—Spicular skeleton—Sclerobasic corals—The structure of a simple sclerodermic corallum—Structure of septa—Development of the corallum—Relations of the polype to the corallum—Composite corals—Chief methods of multiplication in corals—Classification of the Actinozoa—Distribution of the Actinozoa in space—Distribution of the Actinozoa in time, ... 240-260

CHAPTER XVII.

General characters of the Zoantharia—Classification of Zoantharia—Distribution of Zoantharians in time—Characters and divisions of the Madreporaria—Characters and geological distribution of the Madreporaria Aporosa—The Turbinolidæ—Oculinidæ—Pocilloporidæ—Astræidæ—Holocystis—Stauria—Acervularia—Columnaria—Moseleya, ... 261-275

CHAPTER XVIII.

General characters of the Madreporaria Rugosa—Structure of the corallum of the Rugosa—Kunth's law of the development of the septa—Classification of the Rugosa—Cyathophylloid Rugosa—Cyathophyllidæ—Heliophyllidæ—Clisiophyllidæ—Zaphrentoid Rugosa — Zaphrentidæ — Hadrophyllidæ — Palæocyclidæ—Streptelasmidæ—Lindstrœmia—Cystiphylloid Rugosa—Cystiphyllidæ—Calceolidæ, ... 276-302

CHAPTER XIX.

General characters of the Madreporaria Fungida—Plesiofungidæ—Fungidæ—Lophoseridæ—Anabacidæ—Plesioporitidæ—General characters and geological distribution of the Madreporaria Perforata—Eupsammidæ—Madreporidæ—Poritidæ—Favositidæ—Syringoporidæ—Thecidæ, ... 303-323

CHAPTER XX.

General characters of the Alcyonaria—Divisions of the Alcyonaria—Distribution in time—Pseudaxonia—Tubiporidæ—Gorgonidæ—Pennatulidæ—Helioporidæ—Heliolitidæ—Halysitidæ—Tetradiidæ—Chætetidæ—Auloporidæ—Literature of Actinozoa, 324-345

CHAPTER XXI.

The general characters of the Monticuliporoids—Zoological affinities of the Monticuliporoids—Geological distribution—Monticuliporidæ—Fistuliporidæ, ... 346-360

CHAPTER XXII.

The general characters of the Echinodermata—The digestive, ambulacral, and reproductive systems of Echinoderms—Minute structure of the skeleton of the Echinoderms—Bolboporites—Classification of Echinoderms—Distribution of Echinoderms in time, ... 361-365

CHAPTER XXIII.

General characters of the Echinoidea—Structure of the test and its appendages—Classification of the Echinoids—Distribution of the Echinoids in time—Characters and distribution of the Palechinoids—Cystocidaridæ—Bothriocidaridæ—Perischoechinidæ—Characters and distribution of the Euechinoids — Regular Euechinoids—Cidaridæ—Salenidæ—Echinothuridæ—Glyphostomata—Irregular Euechinoids—Conoclypeidæ—Clypeastridæ Echinoconidæ—Cassidulidæ—Holasteridæ—Spatangidæ, 366-390

CHAPTER XXIV.

General characters of the Asteroidea—Integumentary skeleton of the Star-fishes—Ambulacral system and skeleton—Distribution of Asteroids in space and time—Classification—The Encrinasteriæ and their chief types—The Asteriæ veræ—General characters of the Ophiuroidea—Integumentary skeleton of Ophiuroids—Ambulacral system—Reproductive system—Distribution of Ophiuroids in space and time—The Euryalida—The Ophiurida—The Protophiurida—General characters of the Holothuroidea—Remains of fossil Holothurians, . . 391-407

CHAPTER XXV.

General characters of the Pelmatozoa—General characters of the Crinoidea—Structure of Antedon—Development of Antedon—General morphology of the Stalked Crinoids—Classification of the Crinoids—Distribution of the Crinoids in space and in time—Characters of the Palæocrinoidea—Actinocrinidæ—Barrandeocrinidæ—Platycrinidæ—Rhodocrinidæ—Calyptocrinidæ—Ichthyocrinidæ—Crotalocrinidæ—Haplocrinidæ—Symbathocrinidæ—Cupressocrinidæ—Gasterocomidæ — Hybocrinidæ — Heterocrinidæ—Anomalocrinidæ—Belemnocrinidæ—Cyathocrinidæ—Poteriocrinidæ—Astylocrinidæ—Catillocrinidæ—Calceocrinidæ—Characters of the Neocrinoidea—Encrinidæ—Eugeniacrinidæ—Holopidæ — Hyocrinidæ — Plicatocrinidæ — Apiocrinidæ—Bourgueticrinidæ—Pentacrinidæ—Marsupitidæ—Comatulidæ—Saccocomidæ, ... 408-446

CHAPTER XXVI.

General characters of the Cystoidea—Morphology of Cystoids—Distribution of the Cystideans in time—Classification of Cystideans—Suborders and principal genera of the Cystideans—General

characters of the Blastoidea—Morphology of the Blastoids—Distribution of the Blastoids in time—Classification of the Blastoids—Table of the families and genera of Blastoids—Literature of Echinoderms, ... 447-467

CHAPTER XXVII.

General characters of the Annulosa—Supposed remains of fossil Entozoa—Characters of the Anarthropoda—Gephyrea—Myzostomida—Characters and distribution in time of the Annelida—The Tubicolous Annelides—The Errant Annelides—Trails and tracks, ... 468-490

CHAPTER XXVIII.

General characters of the Arthropoda—Distribution of the Arthropoda in time—General characters of the Crustacea—Morphology of the Crustacea—Classification of the Crustacea—Distribution of the Crustacea in time—General characters of the Cirripedia—Divisions of the Cirripedia—The Balanidæ—Verrucidæ—Lepadidæ, ... 491-502

CHAPTER XXIX.

General characters of the Entomostraca—The Lophyropoda—General characters of the Ostracoda—Types of Ostracodes—General characters of the Copepoda—The Branchiopoda—General characters of the Cladocera—Characters and chief types of the Phyllopoda—Characters and types of the Phyllocarida—General characters of the Trilobita—Systematic position and distribution in time of the Trilobites—Families of the Trilobites—The Merostomata—General characters of the Xiphosura—Types of the Xiphosura—Hemiaspidæ—Limulidæ—General characters of the Eurypterida—Systematic position and distribution of Eurypterids—Types of the Eurypterida, ... 503-555

CHAPTER XXX.

General characters of the Malacostraca—Hedriophthalmata—Amphipoda—Isopoda—Thoracostraca—Cumacea—Schizopoda—Stomatopoda—Decapoda—Macrura—Anomura—Brachyura—Literature of Crustacea, ... 556-571

CHAPTER XXXI.

General characters of the Arachnida—Distribution of the Arachnida in space and time—Acarida—Anthracomarti—Adelarthroso-

mata—Pedipalpi—Araneida—General characters of the Myriopoda—Distribution of Myriopods in space and time—Protosyngnatha — Chilopoda — Archipolypoda — Diplopoda — Literature of Arachnida and Myriopoda, ... 572-586

CHAPTER XXXII.

General characters of the Insecta—Distribution of the Insecta in time—Apterous Insects — Palæodictyoptera — Rhynchota—Orthoptera—Neuroptera—Aphaniptera—Diptera—Lepidoptera—Hymenoptera—Strepsiptera—Coleoptera, ... 587-602

CHAPTER XXXIII.

General characters of the Molluscoidea—General characters of the Polyzoa—Structure of the skeleton in the Polyzoa—Classification of the Polyzoa—Distribution of the Polyzoa in time—General characters of the Cyclostomatous Polyzoa—Distribution of Cyclostomata in time—Characters and distribution of the chief groups of Cyclostomata—General characters of the Cheilostomatous Polyzoa—Characters and geological distribution of the chief families of Cheilostomata, ... 603-639

CHAPTER XXXIV.

General characters of the Brachiopoda—Distribution of the Brachiopoda in space and in time—Characters of the Inarticulata—Characters and geological distribution of the Families of Inarticulated Brachiopods—Characters of the Articulata—Characters and geological distribution of the Articulated Brachiopods—Literature, ... 640-679

CHAPTER XXXV.

General characters of the Mollusca—Classification of the Mollusca —Distribution of the Mollusca in space and in time — General characters of the Lamellibranchiata—Structure of the shell of Lamellibranchiates—Distribution of Lamellibranchs in space —Classification of the Lamellibranchs—Distribution of the Lamellibranchs in time, ... 680-693

CHAPTER XXXVI.

Divisions of the Lamellibranchiata—Ostreacea—Pectinacea—Mytilacea—Arcacea—Submytilacea—Erycinacea—Cardiacea—Chamacea—Conchacea—Myacea—Adesmacea—Lucinacea—Tellinacea—Anatinacea, ... 694-752

CHAPTER XXXVII.

General characters of the Gastropoda—Shell of the Gastropods—Odontophore and respiratory organs of Gastropods—Classification of Gastropods—Distribution of Gastropods in space—Distribution of Gastropods in time, ... 753-759

CHAPTER XXXVIII.

Branchiogastropoda—Characters of the Prosobranchiata—Patellidæ—Fissurellidæ—Capulidæ—Velutinidæ—Pleurotomariidæ—Bellerophontidæ—Haliotidæ—Euomphalidæ—Solariidæ—Trochidæ—Turbinidæ—Xenophoridæ—Neritidæ—Neritopsidæ—Helicinidæ—Naticidæ—Paludinidæ—Rissoidæ—Littorinidæ—Scalariidæ—Ianthinidæ—Turritellidæ—Vermetidæ—Cæcidæ—Pyramidellidæ—Pseudomelaniidæ—Melaniidæ—Cyclostomidæ—Aciculidæ—Subulitidæ—Nerineidæ—Cerithiidæ—Aporrhaidæ—Strombidæ—Cypræidæ—Cassididæ—Doliidæ—Ficulidæ—Tritoniidæ—Buccinidæ—Columbellidæ—Purpuridæ—Fusidæ—Muricidæ—Volutidæ—Harpidæ—Olividæ—Cancellariidæ—Conidæ—Pleurotomidæ—Terebridæ, 760-799

CHAPTER XXXIX.

Characters of the Opisthobranchiata—Actæonidæ—Bullidæ—Aplysiadæ—Pleurobranchidæ—Characters and distribution in time of the Heteropoda—Firolidæ—Atlantidæ—Characters of the Pteropoda—Limacinidæ—Cavoliniidæ—Cymbuliidæ—Hyolithidæ—Conulariidæ—Tentaculitidæ—Characters of the Pulmogastropoda—Characters of the Stylommatophora—Testacellidæ—Limacidæ—Helicidæ—Characters of the Basommatophora—Auriculidæ—Limnæidæ—Siphonariidæ—Gadiniidæ, . . 800-815

CHAPTER XL.

Characters of the Polyplacophora—Characters and distribution of the Chitonidæ—Structure of the shell of Chiton—The Palæozoic Chitons—Characters and distribution of the Scaphopoda—Dentalium—Entalis—Siphonodentalium—Cadulus, . 816-820

CHAPTER XLI.

Characters of the Cephalopoda—Classification of the Cephalopoda—Distribution in space—Distribution in time, . . . 821-825

CHAPTER XLII.

General characters of the Tetrabranchiata—Divisions of the Tetrabranchiata — Characters of the Nautiloidea — Orthoceratidæ—Endoceratidæ—Actinoceratidæ—Gomphoceratidæ—Ascoceratidæ — Poterioceratidæ — Cyrtoceratidæ — Lituitidæ — Trochoceratidæ—Nautilidæ—Bactritidæ—Prosiphonate Nautiloids, 826-847

CHAPTER XLIII.

General characters of the Ammonoidea—Structure of the shell in the Ammonoidea—The Aptychus—Zoological affinities of the Ammonoidea—Distribution of the Ammonoidea in time—Clymeniidæ — Goniatitidæ — Arcestidæ — Tropitidæ — Ceratitidæ—Cladiscitidæ—Pinacoceratidæ—Phylloceratidæ—Lytoceratidæ—Ptychitidæ—Amaltheidæ—Ægoceratidæ—Harpoceratidæ—Haploceratidæ—Stephanoceratidæ, ... 848-870

CHAPTER XLIV.

General characters of the Dibranchiate Cephalopods—Skeleton of the Dibranchiates—Classification—Distribution in time—General characters of the Decapoda—Phragmophora—Spirulidæ—Belemnitidæ—Belemnoteuthidæ—Sepiophora—Chondrophora—Characters and distribution in time of the Octopoda—Literature of Mollusca, ... 871-885

CORRIGENDA TO PART II.

Page 397 and page 398, *for* "*Phanerogonia*" and "*Cryptogonia*" *read* "*Phanerozonia*" and "*Cryptozonia.*"

" 451, line 23 from top, *for* "Sporadiporous" *read* "Sporadipodous."

PART I.

GENERAL INTRODUCTION

BY

H. ALLEYNE NICHOLSON

PALÆONTOLOGY.

CHAPTER I.

INTRODUCTION.

Definition of Palæontology.

Palæontology (Gr. *palaios*, ancient ; *onta*, beings ; *logos*, discourse) is the science which treats of the living beings, whether animal or vegetable, which have inhabited this globe at past periods in its history. It is the ancient life-history of the earth, and if its record could ever be completed, it would furnish us with an account of the structure, habits, and distribution of all the animals and plants which have at any time flourished upon the land-surfaces of the globe or inhabited its waters. From causes, however, which will be subsequently discussed, the palæontological record is most imperfect, and our knowledge is interrupted by gaps which not only bear a large proportion to our solid information, but which in many cases are of such a nature that we can never hope to have them filled up.

As Zoology, then, treats of the animals now inhabiting the earth, and as Botany treats of the now existing plants, Palæontology may be defined as the Zoology and Botany of the past, and may be subdivided into the two subjects of Palæozoology and Palæobotany. The study of fossil animals and plants is, however, based upon the knowledge of living animals and plants, and for this reason Palæozoology and Palæobotany are inseparably connected with Neozoology and Neobotany. The materials, again, which fall to be studied by the palæontologist, are drawn entirely from the proper province of the geologist. *Fossils* are derived from *rocks*. It will therefore be necessary to trespass to some extent upon the peculiar domain of the geologist, and to obtain some knowledge of the origin, com-

position, and mode of occurrence of the rocks from which Palæontology obtains its materials. Lastly, Palæontology, apart from its own importance as an independent branch of Zoology, is employed by the geologist to assist him in his determination of the chronological succession of the materials which compose the crust of the earth. Palæontology, therefore, in one of its aspects, is a branch of geological science, and requires separate study in its relation to historical Geology.

Definition of Fossils.

All the natural objects which come to be studied by the palæontologist are termed "fossils" (Lat. *fossus*, dug up). In most cases, fossils, or, as they are often termed, "petrifactions," are actual portions of animal or vegetable organisms, such as the shells of Molluscs, the skeletons of Corals, the bones of Vertebrate animals, the wood, bark, or leaves of plants, &c.; and these may be preserved very much in their original condition, or may have been very much altered by changes subsequent to their burial. Strictly speaking, however, by the term "fossil" is understood "any body, *or the traces of the existence of any body*, whether animal or vegetable, which has been buried in the earth by natural causes" (Lyell). We shall find, therefore, that we must include under the head of fossils objects which at no time themselves formed parts of any animal or vegetable, but which, nevertheless, point to the former existence of such organisms, and enable us to reason as to their nature. Under this head come such fossils as the moulds or "casts" of shells and the footprints or markings left by various animals upon sand or mud.

In the great majority of cases fossils are the remains of animals or plants which are now *extinct*—that is to say, which no longer are in existence, but have entirely disappeared from the earth's surface. In some cases, however, fossils are the remains of *recent* animals—that is, of animals which are still found in a living condition upon the globe. The term "sub-fossil," sometimes applied to these, has been more appropriately applied in another sense, and is best discarded in this connection. In any case, the fact that a given specimen belongs to an extinct species of animal or plant, or that it is referable to some existing form, does not enter in any way whatever into the determination of the question as to whether or not it is truly a *fossil*. If such a specimen is found in those portions of the earth's crust which we can show by other evidence to have been formed prior to the establishment of the existing terrestrial order, then it is a fossil; while any remains, even though belonging to the same animal, which are found in deposits which have been formed during the historical period, would be, strictly speaking, referred to

the domain of the neozoologist or the neobotanist, and would not rightly be termed "fossils." It must be admitted, however, that in approaching the "Recent" period of the earth's history, it becomes a matter of difficulty—in some cases an impossibility—to draw any precise line between fossil and recent specimens.

The terms "fauna" and "flora" are employed in Palæontology much as they are by the student of recent forms, to mean the entire assemblage of the animals or of the plants respectively belonging to a particular region or a particular time. Thus we may speak of the "fauna" of the Carboniferous Period, or the "flora" of the Tertiary Epoch, or the fauna of the Chalk, or of any other set of beds.

Fossilisation.

The term "fossilisation" may be applied in a general sense to all the processes through which an organic body passes in order to become a fossil. Here we need only consider the three leading forms in which fossils present themselves. In the first instance, the fossil is to all intents and purposes an actual organic remain, being itself a fragment of an animal or plant. Thus we may meet with fossil bones, shells, or wood, which may have undergone certain changes, such as would be produced by pressure, by the deprivation of organic matter originally present, or by more or less complete infiltration with mineral matter, but which, nevertheless, are practically the real bodies they represent. As a matter of course, it is in the more modern formations that we find fossils least changed from their primitive condition, but almost all formations contain some fossils in which the original structure is more or less completely retained.

In the second place, we very frequently meet with fossils in the state of "casts" or moulds of the original organic body. What occurs in this case will be readily understood, if we imagine any common bivalve shell, as an Oyster, or Mussel, or Cockle, embedded in clay or mud. If the clay were sufficiently soft and fluid, the first thing would be that it would gain access to the interior of the shell and would completely fill up the space between the valves. The pressure, also, of the surrounding matter would ensure that the clay would everywhere adhere closely to the exterior of the shell. If now we suppose the clay to be in any way hardened so as to be converted into stone, and if we were to break up the stone, we should obviously have the following state of parts. The clay which filled the shell would form an accurate cast or mould of the *interior* of the shell, and the clay outside would give us an exact impression or cast of the *exterior* of the shell (fig. 1). We should have, then, two casts, an interior and an exterior, and the two would be very different from one another, since the inside of a shell is very unlike the

outside. In the case, in fact, of many Molluscan shells, the interior cast is so unlike the exterior or unlike the shell itself, that it may be difficult to determine the true origin of the former.

It only remains to add that there is sometimes a further complication. If the rock be very porous and permeable by water, it may happen that the original shell is entirely dissolved away, leaving the interior cast or "mould" loose, like the kernel of a nut, within the case formed by the exterior cast. Or it may happen that subsequent to the attainment of this state of things, the space thus left vacant between the interior and exterior cast—the space, that is, formerly occupied by the shell itself—may be filled up by some foreign mineral deposited there by the infiltration of water. In this last case the splitting open of the rock would reveal an interior cast, an exterior cast, and finally a body which would have the exact form of the original shell, but which would really be of much later origin and would not exhibit under the microscope the minute structure of shell.

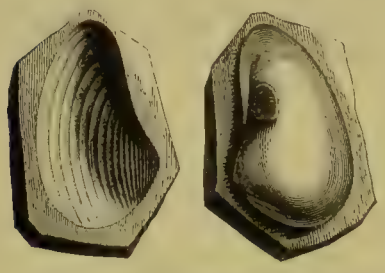


Fig. 1.—*Trigonia longa*, showing casts of the exterior and interior of the shell. Neocomian.

In the third class of cases we have fossils which present with the greatest accuracy the external form, and sometimes even the internal minute structure, of the original organic body, but which, nevertheless, are not themselves truly organic, but have been formed by a "replacement" of the particles of the primitive organism by some mineral substance. The most beautiful example of this is afforded by fossil wood which has been "silicified" or converted into flint. In this case we have a piece of fossil wood, which presents the rings of growth and fibrous structure of wood, and under the microscope exhibits even the minutest vessels which characterise ligneous tissue. The whole, however, instead of being composed of the original carbonaceous matter of the wood, is now converted into pure flint. The only explanation which can be given of this by no means very rare phenomenon, is that the wood must have undergone a slow process of decay in water holding silica or flint in solution. As each particle of the wood was removed by decay, its place was taken by a particle of flint deposited from the surrounding water, till ultimately the entire wood was silicified. The replacing substance is by no means necessarily flint, but may be iron-pyrites, oxide of iron, sulphur, malachite, magnesite, talc, &c.; and it is not uncommon to find many other fossils besides wood preserved in this way, such as shells, corals, or sponges.

The *replacement* of the original substance of a fossil by some

foreign body is thus a matter of common occurrence, but it is by no means always easy to determine whether or not such replacement has taken place. By far the commonest mode of replacement is that whereby an originally calcareous skeleton is replaced by silica. This process of "silicification"—of the replacement of *lime* by *silica*—is not only an extremely common one, but it is also a readily intelligible one; since carbonate of lime is an easily and flint a hardly soluble substance. It is thus easy to understand that originally calcareous fossils, such as the shells of Mollusca, or the skeletons of Corals, should have in many cases suffered this change, long after their burial in the rock, their carbonate of lime being dissolved away, particle by particle, and replaced by precipitated silica, as they were subjected to percolation by heated or alkaline waters holding silica in solution.

In a large number of cases of silicification, the minute *structure* of the fossil which has been subjected to this change is found to have been more or less injuriously affected, and may be altogether destroyed, even though the *form* of the fossil be perfectly preserved. This is the rule where the silicification has been secondary, and has taken place at some period long posterior to the original entombment of the fossil in the enveloping rock; whereas if the original fossilisation has been effected by infiltration with silica in the first instance, then the minute structure is usually perfectly preserved. In secondary silicification, as seen in corals and shells, the carbonate of lime of the original fossil is gradually more or less completely replaced by silica, the process beginning on the exterior and gradually extending inwards. In the first stage of the process, the outer layer of the fossil very commonly becomes more or less largely converted into, or covered by, small circular deposits of silica, having the form of a central boss surrounded by one or more concentric rings ("orbicular silica" or "Beekite markings"). If the process goes on, the whole of the fossil may ultimately become converted into flint. Secondarily silicified fossils, though ill adapted for microscopic examination, are often of great beauty, as they commonly "weather out" from the more readily soluble limestone in which they are embedded, and can thus be obtained in absolute entirety.

When we meet with fossils, such as those alluded to above, which we *know* to have been originally calcareous, but which we now find, unchanged in form, although converted into flint, then we cannot doubt that we have to deal with cases of "silicification," and that the primitive skeleton of lime has in these cases been slowly, and more or less perfectly, replaced by silica. We cannot, however, speak in such a positive manner as to fossils which we now find to be composed of flint, but as to the original constitution of which we cannot be certain. We find, namely, some fossils which are of uncertain affinities, and which sometimes occur in a siliceous and sometimes in a calcareous state. If we are not positive as to the zoological position of these fossils, or if they belong to a group of animals in

which we find the living forms to possess sometimes a calcareous and at others a siliceous skeleton, then it is obviously a matter of extreme difficulty to determine whether the extinct forms were really composed of lime or of flint. In such cases, we must be guided principally by the condition of preservation of the fossils which occur associated with such obscure forms in the same beds; the fact that the associated remains are converted into flint pointing to the probability that the problematical forms were originally calcareous, and *vice versâ*. In the case, also, of all fossils which present themselves sometimes in a siliceous and sometimes in a calcareous form, there is always the *presumption* that the skeleton was originally composed of *lime*, this presumption being based upon the fact that the conversion of the calcareous skeletons of animals into silica by a process of replacement is an unquestionable, an extremely common, and a readily intelligible occurrence.

Until recently, indeed, naturalists never allowed themselves to contemplate the alternative possibility of an originally *siliceous* skeleton being replaced by *lime;* but we have now unequivocal evidence that this anomalous mode of replacement is of not very uncommon occurrence. The researches of Zittel, Hinde, and Sollas have, in fact, proved that the colloid silica of the siliceous skeletons of the Flinty Sponges is comparatively unstable, and that under certain circumstances it can be readily dissolved in water. Hence these Sponges are commonly found in the fossil condition with the silica of the original skeleton more or less extensively replaced by carbonate of lime, or by oxide or sulphide of iron. When the replacing agent is lime, it is found not only that the microscopic structure of the original skeleton has been completely lost; but that the lime is always in the *crystalline* condition, consisting of unoriented crystals of calcite. This latter fact affords conclusive proof that the skeleton was not primitively calcareous, but that the lime is of secondary origin and has replaced some other material

In any case we must carefully distinguish between *replacement*, whether by flint or any other mineral, and *infiltration*, the latter being merely the process whereby the cavities and natural vacuities of a fossil are liable to become filled by some mineral substance, subsequent to its entombment in sediment. When such a fossil as a shell or a coral, for example, becomes buried in the sandy, calcareous, or argillaceous mud at the bottom of the sea, the surrounding sediment often does not penetrate into the deeper parts of the fossil, and there are thus left in its interior certain empty spaces, into which the surrounding water makes its way by percolation. Any mineral substances, such as carbonate of lime or silica, which may be contained in solution in the water, are then liable to undergo precipitation, and to be deposited in a solid form within the fossil.

All the natural cavities of a fossil, even down to the minutest microscopic pores or tubes, may in this way become filled with some such infiltrated material, the two commonest agents in this process being lime and flint. If the skeleton of the fossil be a calcareous one, while the infiltrating material has been some less soluble substance, such as silica or some silicate, then the skeleton may be artificially or naturally dissolved away, leaving a *cast* of the internal cavities of the fossil formed of the infiltrated matter. Thus the minute shells of *Foraminifera* are often infiltrated with the silicate glauconite, and exquisitely perfect casts of their interior cavities are subsequently formed by dissolution of the shell itself. In this way, as we shall see hereafter, deposits of greensand have been sometimes produced.

Definition of Rock.

The crust of the earth consists of various different materials, produced at different successive periods, occupying certain definite spaces, and not confusedly mixed together, but, on the contrary, exhibiting a definite and discoverable order of arrangement. All these materials, however different in appearance, texture, or mineral composition, are called "rocks" by the geologist. The term "rock," then, is to be understood as applying to *all* the materials which compose the crust of the earth. In the language of geology, the finest mud, the loosest sand, and the most incoherent gravel, are just as much *rocks* as are the hardest and most compact granites or limestones.

Classification of Rocks.

For the purposes of the palæontologist all the rocks which enter into the composition of the solid exterior of the earth may be divided into two great classes: 1. The Igneous Rocks, which are formed within the body of the earth itself, and owe their structure and origin to the action of heat; and 2. the Aqueous or Sedimentary Rocks, which are formed at the surface of the earth, and owe their structure, at any rate in part, to the mechanical action of water. The Igneous Rocks are principally formed below the surface of the earth, are as a general rule destitute of organic remains or fossils, and are mostly in the form of *unstratified* masses. The Aqueous and Sedimentary Rocks are formed at the surface by the disintegration and reconstruction of previously existing rocks, or by the vital chemistry of animals or plants, are mostly fossiliferous, and are *stratified—i.e.*, are arranged in distinct layers or "strata." The Aqueous Rocks, as containing fossils, are the only rocks with which it is essential for the palæontologist to be acquainted, and we shall very briefly consider their leading physical characters, their

chief varieties, their mode of origin, and their historical succession. It should be borne in mind, however, that there are cases in which strictly volcanic deposits may come to contain the remains of animals and plants. Thus, animals and plants may be enveloped and entombed in showers of volcanic ashes falling upon land, and deposits of subaerial volcanic ash may thus become fossiliferous. Moreover, it is very common for volcanic ashes to fall in vast quantities into the sea or into a lake, when they become subjected to the action of water, and may envelop the animals living at the bottom. Hence it is by no means unusual to meet in the crust of the earth with more or less extensive deposits of volcanic ashes, which though igneous in origin are secondarily aqueous, being not only stratified but also containing the remains of aquatic animals.

CHAPTER II.

THE FOSSILIFEROUS ROCKS.

THE Sedimentary or Fossiliferous Rocks form the greater portion of that part of the earth's crust which is open to our examination, and are distinguished by the fact that they are regularly "stratified," or arranged in distinct and definite layers or "strata." These layers may consist of a single material, as in a block of sandstone, or they may consist of different materials. When examined on a large scale, they are always found to consist of alternations of layers of different mineral composition. We may examine any given area, and find in it nothing but one kind of rock—sandstone, perhaps, or limestone. In all cases, however, if we extend our examination sufficiently far, we shall ultimately come upon different rocks; and, as a general rule, the thickness of any particular set of beds is comparatively small, so that different kinds of rock alternate with one another in comparatively small spaces.

As regards the origin of the Sedimentary Rocks, they are for the most part "derivative," being derived from the wear and tear of pre-existent rock. Sometimes, however, they owe their origin to chemical or vital action, when they would more properly be spoken of simply as Aqueous Rocks. As to their mode of deposition, we are enabled to infer that the materials which compose them have formerly been spread out by the action of water, from what we see going on every day at the mouths of our great rivers, and on a smaller scale wherever there is running water. Every stream, where it runs into a lake or into the sea, carries with it a burden of mud, sand, and rounded pebbles, derived from the waste of the rocks which form its bed and banks. When these materials cease to be impelled by the force of the moving water they sink to the bottom, the heaviest pebbles, of course, sinking first, the smaller pebbles and sand next, and the finest mud last. Ultimately, therefore, as might have been inferred upon theoretical grounds, and as is proved by practical experience, every lake becomes a receptacle for a series

of stratified rocks produced by the streams flowing into it. These deposits may vary in different parts of the lake, according as one stream brought down one kind of material and another stream contributed another material; but in all cases the materials will bear ample evidence that they were produced, sorted, and deposited by running water. The finer beds of clay or sand will all be arranged in thicker or thinner layers or laminæ; and if there are any beds of pebbles these will all be rounded or smooth, just like the water-worn pebbles of any brook-course. In all probability, also, we should find in some of the beds the remains of fresh-water shells, plants, or other organisms which inhabited the lake at the time these beds were being deposited.

In the same way large rivers—such as the Ganges or Mississippi—deposit at their mouths much of the material which they bring down, forming in this way their "deltas." Whenever such a delta is cut through, either by man or by some channel of the river altering its course, we find that it is composed of a succession of horizontal layers or strata of sand or mud, varying in mineral composition, in structure, or in grain, according to the nature of the materials brought down by the river at different periods. Such deltas, also, will contain the remains of animals which inhabit the river, with fragments of the plants which grew on its banks, or bones of the animals which lived in its basin.

Lastly, the sea itself—irrespective of the materials delivered into it by rivers—is constantly preparing fresh stratified deposits by its own action. Upon every coast-line the sea is constantly eating back into the land and reducing its component rocks to form the shingle and sand which we see upon every shore. The materials thus produced are not, however, lost, but are ultimately deposited elsewhere in the form of new stratified accumulations, in which are buried the remains of animals inhabiting the sea at the time.

Whenever, then, we find anywhere in the interior of the land any series of beds having these characters—composed, that is, of distinct layers, the particles of which, both large and small, show distinct traces of the wearing action of water—whenever and wherever we find such rocks, we are justified in assuming that they have been deposited by water in the manner above mentioned. Either they were laid down in some former lake by the combined action of the streams which flowed into it; or they were deposited in some portion of the course of an ancient river; or they were laid down at the bottom of the ocean. In the first two cases, any fossils which the beds might contain would be the remains of fresh-water or terrestrial organisms. In the last case, the majority, at any rate, of the fossils would be the remains of marine animals.

The term "formation" is often employed by geologists in a loose

general sense to signify "any group of rocks which have some character in common, whether of origin, age, or composition" (Lyell); so that we may speak of stratified and unstratified formations, aqueous or igneous formations, fresh-water or marine formations, and so on.

Chief Divisions of the Aqueous Rocks.

The Aqueous Rocks may be divided into two great sections, the Mechanically-formed and the Chemically-formed, including under the last head all rocks which owe their origin to vital action, as well as those produced by ordinary chemical agencies. It must not be forgotten, however, that such a division, though convenient in practice, is largely artificial. Thus many organically-formed rocks are to a large extent the product of mechanical action, since, though consisting of the skeletons of organisms, their component materials have been mechanically broken down and transported by water. Moreover, no sharp line of demarcation can be drawn between the above two groups of rocks, innumerable transitions existing between rocks which are purely mechanical in origin and those which are the direct result of vital action.

A. Mechanically-formed Rocks.—These are all those Aqueous Rocks of which we can obtain proofs that their particles have been mechanically transported to their present site. Thus, if we examine a piece of conglomerate or pudding-stone, we find it to be composed of a number of rounded pebbles embedded in an enveloping paste or matrix. The pebbles are worn and rounded, and thus show that they have been subjected to much mechanical attrition, whilst they have been mechanically transported for a greater or less distance from the rock of which they originally formed part. In the case of an ordinary sandstone, the component grains of sand are equally the result of mechanical attrition, and have been equally transported from a distance. In the case of still finer rocks, such as shale, the particles have been so much water-worn that their source cannot be recognised, though a microscopical examination would reveal that their edges were all worn and rounded. It follows from this that the mechanically-formed Aqueous Rocks are such as can be proved to have been *derived* from the abrasion of other pre-existent rock: hence they are often spoken of as "Derivative Rocks." Every bed, therefore, of any mechanically-formed rock, is the equivalent of a corresponding amount of destruction of some older rock.

The mechanically-formed Rocks may be divided into the two groups of the Arenaceous or Siliceous Rocks, and the Argillaceous or Aluminous Rocks. In the Arenaceous group are those Aqueous Rocks which are mainly composed of smaller or larger grains of flint or silica. The chief varieties are the various kinds of sand and

sandstone, grits, and most conglomerates and breccias. In the Argillaceous group are those Aqueous Rocks which contain a certain amount of clay or hydrated silicate of alumina. Under this head come clays, shales, marls, clay-slate, and most flags or flagstones. In nature there exists, it need hardly be said, no rigid line which separates the Arenaceous from the Argillaceous rocks. The two groups are connected together by endless transitional forms, and we must regard all the mechanically-formed rocks as variable mixtures of different ingredients, their precise character depending on the predominance of some one constituent.

B. Chemically-formed Rocks.—In this section are comprised all those Aqueous Rocks which have been formed by chemical agencies. Since, however, many of these chemical agencies are exerted through the medium of living beings, whether animals or plants, we get into this section a number of what may be called "organically-formed" rocks. The most important of the Chemically-formed Rocks are the so-called Calcareous Rocks, comprising all those which contain a large proportion of carbonate of lime, or are wholly made up of this substance; but there are other rocks, of different composition, formed by chemical or organic agency, which may be briefly noticed.

As an example of a rock the origin of which is purely chemical, we may take *rock-salt* or *sodium chloride*, extensive deposits of which occur in formations of all ages, from the Silurian upwards. Whatever may have been the precise mode in which these deposits were formed, it is quite certain that the salt existed, to begin with, in solution in water, and that its assumption of the solid form was the result simply of precipitation. Hence, rock-salt is invariably composed of larger or smaller crystals of sodium chloride, though not uncommonly rendered impure by intermixture with sand or clay.

Another rock which may be regarded as a direct product of chemical action, apart from the operation of living beings, is *gypsum* or *calcium sulphate*. This substance, apart from other modes of occurrence, is not uncommonly found interstratified with the ordinary sedimentary rocks, in the form of more or less irregular beds; and in these cases it has a certain palæontological importance, as occasionally yielding well-preserved fossils. In general appearance, gypsum, when occurring in mass, is usually a whitish, yellowish, or reddish granular rock, which can be easily shown by the microscope to be composed of crystals of calcium sulphate. Very commonly, indeed, the rock is as coarsely crystallised as loaf-sugar, or more so, and the microscope is not needed for the recognition of its true structure. With regard to its mode of origin, there is no reason to doubt that deposits of gypsum are formed by the direct precipitation of calcium sulphate from solution in water, without the inter-

vention of living beings; though it is possible that in some cases the chemical changes which have resulted in the production of masses of gypsum may have been secondary, and may have acted at some period posterior to the original deposition of the rocks associated with these.

Another lime-salt which owes to chemical action its present form, and its present relations to the rocks with which it is associated, is *phosphate of lime*. Calcium phosphate occurs in the form of larger or smaller crystals (apatite) in many crystalline rocks, whether these be metamorphic or igneous in origin. It also sometimes occurs in considerable beds (phosphorite) in formations of various ages; and it occurs abundantly in the form of nodules in some parts of the Secondary and Tertiary deposits. It likewise may occur disseminated through the ordinary stratified rocks in such a condition as not to be capable of detection save by chemical analysis, as has been shown by Dr Hicks in the case of the Cambrian rocks of Wales. When it is found in the crystalline or in the massive condition, there is no reason to doubt that calcium phosphate is the product of direct chemical action. Even in these cases, however, it is quite possible that it may have been sometimes derived in the first place from the skeletons or excrements of animals. Phosphate of lime forms the larger proportion of the earthy matter of the bones in Vertebrate animals, and also occurs in less amount in the skeletons of certain of the Invertebrates (*e.g.*, *Lingula* and *Discina*, among the Brachiopods; *Conularia* and *Hyolithes*, among the Pteropods; and the *Crustacea* in general). Phosphate of lime is thus, perhaps even more distinctively than carbonate of lime, an organic compound. When calcium phosphate occurs minutely disseminated through a rock, it is tolerably certain that it has been derived from animals and plants. It is also almost certain that the phosphate of lime in the so-called "coprolites" of the Cambridge Greensand, as in other similar phosphatic nodules, is organic in origin. Some of these nodules consist of organisms, such as Sponges, infiltrated with phosphate of lime, but most of them would seem to have been formed by a process of segregation similar to that which has given rise to nodules of clay-ironstone or of carbonate of lime in beds of shale. The name of "coprolites" given to these phosphatic nodules is founded upon a misconception, as they are not actually the fossilised excrements of animals. In various formations, however, there are found genuine "coprolites"—*i.e.*, the petrified excreta of Fishes, Reptiles, or Mammals,—and these are largely composed of phosphate of lime.

By far the largest and most important group of the chemically-formed rocks is that of the *Calcareous Rocks*, comprising all those rocks in which carbonate of lime is the predominating ingredient, and which are therefore spoken of by the general name of *limestones*.

In all cases, the carbonate of lime which exists in a limestone has previously existed in solution in water, either in the water of a spring, river, or lake, or in that of the ocean itself. Owing, in fact, to the ready solubility of calcium carbonate in water holding in solution a certain proportion of carbon dioxide, a larger or smaller quantity of this mineral is invariably found dissolved in all natural waters, whether fresh or salt, since these waters are always to some extent charged with this solvent gas. There are two principal methods by which the carbonate of lime held in solution in water may again assume the solid form. One of these methods consists in the chemical precipitation of the carbonate of lime from the water. This takes place whenever the carbonic acid in the water becomes so far reduced in quantity that it is no longer able to retain in solution all the lime that had been previously dissolved; or whenever the water undergoes partial or complete evaporation; or, again, when water which had been enabled by a high temperature to take up an excess of lime, is subjected to cooling. Various well-known calcareous deposits, such as the "stalactites" and "stalagmites" of limestone caves, and the "calcareous tufa" and "travertine" of springs, are produced in this way by the direct precipitation of carbonate of lime from solution. All limestones deposited in this chemical way directly from saturated solutions are necessarily composed of larger or smaller crystals of carbonate of lime, and the microscope will show that their structure is more or less clearly *crystalline*. They may contain the remains of animals or plants, as is not uncommon in the spongy calcareous tufa deposited by "petrifying springs"; but as such remains are usually only *encrusted* by the precipitated lime, and are not infiltrated, they generally become dissolved out in the course of time, leaving cavities which mark their former presence. Calcareous deposits formed by direct precipitation occasionally occur on a large scale, and thus become geologically important, but the ordinary limestones are formed in a different way, and are of much greater palæontological interest.

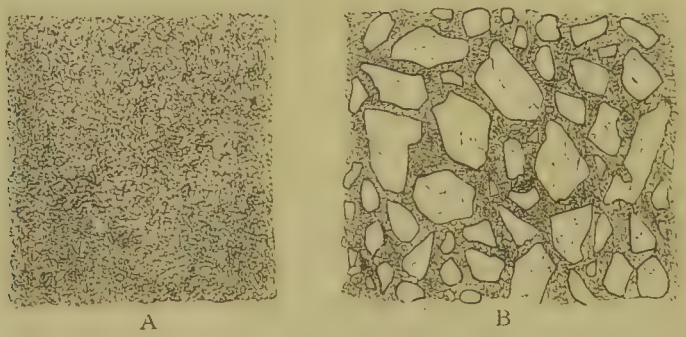
By far the most general method in which the dissolved carbonate of lime in water may be converted into the solid form is by the vital chemistry of animals and plants. Very many animals, and a considerable number of plants, have the power of abstracting from the water the carbonate of lime which it holds in solution, and of building up in this way a calcareous skeleton. Hence, while the waters which percolate through the earth's crust are constantly taking up fresh carbonate of lime, this is being as constantly removed from the waters of rivers, lakes, and the sea, and again converted into the solid form, by the agency of living beings. It is owing to the fact that animal life is much more abundant in the sea than in rivers and lakes, that sea-water contains a proportionately smaller proportion of

dissolved lime than fresh waters, in spite of the circumstance that rivers are constantly pouring into the sea vast quantities of this substance.

Considering the constant production of carbonate of lime by various animals and plants, it is not surprising to find on investigation that many limestones are more or less extensively composed of the skeletons of living beings. Most limestones are therefore, more or less clearly, *organic* rocks. There are, however, two methods—not always very clearly separated from one another—in which an organic limestone may be formed. In one set of cases, the limestone is the result of the accumulation of the calcareous skeletons of animals in the place where these organisms actually lived and grew. This is seen occasionally where a limestone has been formed by the growth of innumerable generations of sedentary Molluscs, such, for example, as Oysters. Some Crinoidal limestones have also been formed by the accumulation of Crinoids in place; and many of the more modern coral-limestones are similarly the result of the growth of the lime-producing polypes in the locality where we now find the rock. In another and more extensive set of cases, the limestone has been formed by the gradual accumulation of the skeletons of animals or plants which lived in some place more or less widely removed from that occupied by the limestone itself. Thus, extensive calcareous deposits may be formed at the bottom of the deep sea by the slow accumulation of the calcareous skeletons of animals which live at the surface of the ocean, and the shells of which fall to the bottom on the death of the animal which produced them. This is seen in certain Foraminiferal limestones and in Pteropodal limestones, though in all such cases the rock is in part made up of the skeletons of animals which actually lived at the bottom of the sea. In other cases, the calcareous skeletons of animals are thrown up in great banks by the action of the sea in the neighbourhood of land. This is the case, for example, with the great accumulations of shell-sand on many parts of our shores, or with the still more extensive deposits of coral-sand in warm seas. In such cases, the limestone is so far *organic* that it is formed mainly out of the skeletons of lime-secreting animals or plants, but it is also so far *mechanical* that the actual formation of the limestone has been due to the breaking up and wearing down of these skeletons by the movements of the waves of the sea.

If this wearing-down action has been sufficiently long-continued and sufficiently complete, we may not be able to recognise in the limestone many, or indeed any, actual fragments of shells or other animal structures; but the rock may appear under the microscope as a fine-grained calcareous mud, made up of minute, mostly non-crystalline granules of carbonate of lime (fig. 2, A). This is the case, for

example, with some limestones of quite recent date, and with the so-called "lithographic" limestones of various geological periods from the Ordovician onwards. Similar fine-grained calcareous muds may likewise be formed by the slow digestion and consequent disintegration of the calcareous skeletons of animals and plants, which takes place when such skeletons are long exposed to the action of sea-water. In other cases, again, a calcareous mud of the kind here spoken of may be produced by the wearing down of previously exist-



A B

Fig. 2.—A, Thin section of lithographic limestone, Jurassic, Solenhofen, greatly magnified. The rock is a fine-grained calcareous mud, for the most part non-crystalline. B, Thin section of an arenaceous limestone from the Middle Permian of Westmorland. The rock is largely mechanical in origin, angular fragments of quartz being cemented together by a crystalline dolomitic matrix. (Original.)

ing limestones. More commonly the abrasive action of the sea has not been sufficiently prolonged or severe to reduce the calcareous fragments to the form of mere calcareous grains, in which the organic structure is no longer perceptible. Hence the great majority of limestones, when examined microscopically, are found to consist of more or less complete skeletons, or portions of the skeletons, of different kinds of lime-producing animals or plants, cemented together by a general crystalline or granular matrix. The general mode of origin of such limestones is rendered sufficiently clear by an investigation of calcareous deposits now in process of formation. Such a limestone to begin with exists in the form of an accumulation of entire or fragmentary calcareous skeletons, of all shapes and sizes, loosely heaped together, and more or less extensively separated by vacant spaces. In the process of consolidation, the irregular lacunæ between the component fragments of the mass may become infiltrated with fine calcareous mud, produced by the disintegration and wearing down of the superficial portions of the mass; and the resulting rock will then have the structure of a granular matrix enclosing innumerable entire or fragmentary organisms. An excellent example of such a rock is to be obtained in the White Chalk (fig. 3), which consists of innumerable organic fragments, mostly referable to the

Foraminifera, cemented together by a fine calcareous mud, and which was probably formed in water of considerable depth. In the more ordinary limestones—most of which have been formed close to a shore-line—the original accumulation of partially broken-up calcareous skeletons is subjected to the percolation through its mass of water holding carbonic acid in solution. As the result of this, partial solution of the mass takes place, and the dissolved carbonate of lime is ultimately deposited in the form of calcite, the rock thus

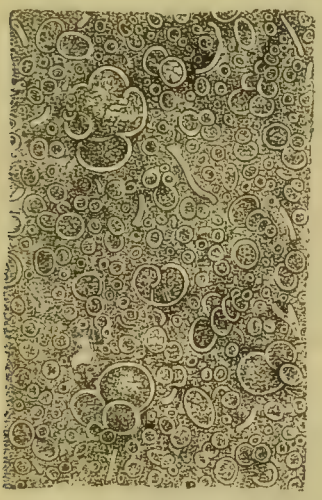


Fig. 3.—Thin section of White Chalk, from Sussex, enlarged about fifty times. The matrix is a calcareous mud, and the contained organisms are mostly entire or broken Foraminifera. (Original.)

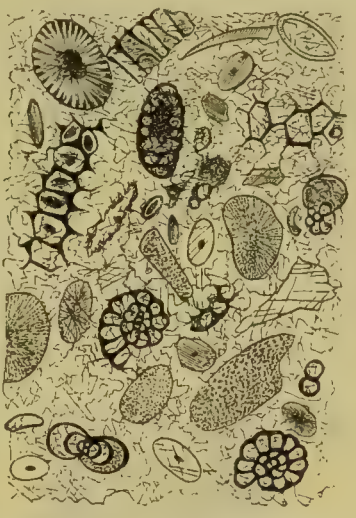


Fig. 4.—Thin section of Carboniferous limestone, from Shap, enlarged about fifteen times. The matrix is crystalline, and the included organisms are Foraminifera, calcareous Algæ, joints of Crinoids, &c. (Original.)

assuming the character of a congeries of organic fragments bound together by a general matrix of crystalline carbonate of lime (fig. 4). Even accumulations of sand may be in this way subjected to the percolation of acidulated water holding lime in solution, and may thus be converted into arenaceous limestones, in which angular quartz-grains are united by a matrix of crystalline carbonate of lime (fig. 2, B). The microscope shows us that very many of the limestones composing the crust of the earth, of all geological ages except the most ancient, have been formed in the general method above described. Limestones of essentially similar structure are also now in process of formation on a large scale. This is specially seen in the warm seas of the coral-region, where the broken down coral-sand commonly becomes converted in time into a hard, crystalline or semi-crystalline limestone; and we may occasionally see the same process at work, on a smaller scale, in the shell-sand of our own shores.

It follows from the above, that the formation of the crystalline matrix of an ordinary limestone is always secondary to the accumulation of the

organic fragments which compose the mass of the rock. In some cases the matrix has been deposited in the first instance in a crystalline form, and is the result of the percolation through the mass of water charged with carbonate of lime in solution. In other instances, the matrix has, to begin with, been composed of a fine calcareous mud, which has later undergone crystallisation, as the result of secondary chemical and mechanical changes. Sometimes this superinduced crystallisation may be the result of pressure; in other cases it may be caused by the percolation through the rock of heated or carbonated water; while in many instances it is connected with the process of dolomitisation.

In this process of superinduced crystallisation, the organic fragments contained in the rock usually show themselves more stable than does the matrix. Hence the matrix may become more or less highly crystalline, while the included organic fragments remain more or less distinct and unaffected. It often happens, however, as specially insisted upon by Dr Sorby, that the fragments of calcareous organisms have crystallised along with the surrounding matrix, in such a manner as to have more or less extensively lost not only their organic structure but also their external outline. There are various degrees in which this superinduced crystallisation, and consequent obliteration, of the included organic fragments in a limestone takes place. It is noticeable, however, that the agencies which give rise to this condition are not necessarily of any great intensity, since complete crystallisation and obliteration of the included organic remains may occur in modern calcareous deposits (*e.g.*, some coral-lime-

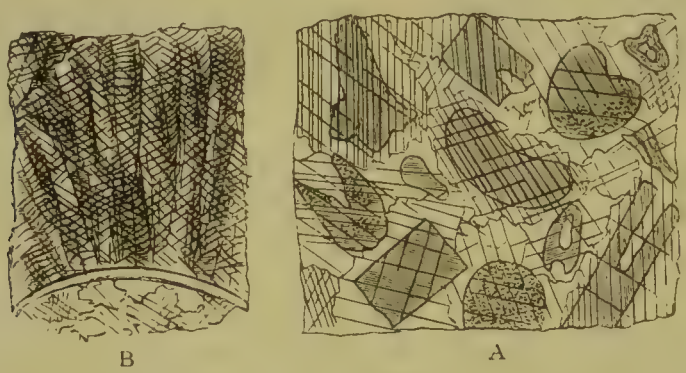


Fig. 5.—A, Section of Ordovician limestone, from Keisley, Westmorland, in which the crystallisation of the matrix has extended to the included fragments of Crinoids, as shown by the continuation of the cleavage-planes from one to the other. Enlarged about five times. B, Fibro-crystalline structure developed in the same limestone, considerably enlarged. (Original.)

stones). An interesting example of this phenomenon is commonly seen in Crinoidal limestones, in which the entire rock may be so crystallised that the cleavage-planes of the calcite run continuously through both the matrix and the included fragments of Crinoids, the latter nevertheless preserving their outlines (Fig. 5, A.)

In many of the older limestones, portions of the rock often exhibit a peculiar fibro-crystalline structure, being composed of feather-like columns of crystalline carbonate of lime, placed side by side and intersected by a double cleavage. Sections of such fibro-crystalline masses (Fig. 5, B), examined microscopically, commonly show, therefore, a characteristic pinnate or "herring-bone" structure, due to the crossing of the two sets of cleavage-planes. This remarkable structure is obviously the

result of secondary changes affecting the limestone. It is of frequent occurrence in the calcareous material which occupies the interior of fossils, such as the shells of Mollusca or the crusts of Trilobites, in which case the columns radiate from the surface of attachment. In other cases, it occupies irregular winding spaces in the rock, when it exhibits a concentrically banded structure, indicating its formation in successive layers, while the constituent fibres radiate inwards in all directions from the bounding surfaces of the mass. Under ordinary conditions, this peculiar fibro-crystalline structure can only be regarded as purely inorganic. In some instances, however, an apparently identical structure is produced by the partial crystallisation of organic remains, such as the calcareous skeletons of Stromatoporoids or Corals. It would appear that the so-called *Stromatactis* of Monsieur E. Dupont, which plays a very important part in the formation of some of the Devonian limestones of Belgium, is really of the nature of the above-mentioned fibro-crystalline masses, being partly of inorganic origin, and probably in part the result of secondary change in suitable fossils, such as Stromatoporoids.

Any of the great groups of Invertebrates in which a calcareous skeleton is produced may take a more or less prominent part in the formation of a limestone; and the principal facts connected with this subject will be dealt with in greater detail in treating of each group of animals separately. It may be well, however, to indicate here, in the briefest manner, the chief groups of organisms, whether animal or vegetable, which may be considered as pre-eminently makers of limestones. As regards animals, a very important place must be assigned to the *Foraminifera*, a group of the *Protozoa* in which a calcareous shell is commonly developed. So far as the older Palæozoic limestones (Ordovician, Silurian, and Devonian) are concerned, it is noteworthy that in very few instances, so far as yet known, do the tests of *Foraminifera* constitute a prominent constituent of the rock. In all the later formations, however, beginning with the Carboniferous, we meet with limestones which are more or less highly charged with the calcareous tests of these minute organisms, sometimes in such numbers that the rock becomes what may be properly called a "Foraminiferal limestone" (fig. 6). Of this nature are the "Saccammina limestone" of the North of England, the "Endothyra limestone" of North America, and the "Fusulina limestone" of Russia, all of which are of Carboniferous age. Of the Foram-

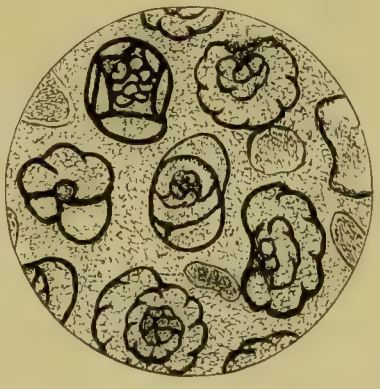


Fig. 6.—Section of Carboniferous limestone from Spergen Hill, Indiana, U.S., showing numerous large-sized *Foraminifera* (*Endothyra*) and a few oolitic grains, magnified. (Original.)

iniferal limestones of the Mesozoic period the most interesting and important is the White Chalk, the characters of which will be considered more fully later on. Lastly, in the Tertiary period there are various well-known Foraminiferal limestones, of which the most important and most widely distributed is the great calcareous deposit known as the "Nummulitic limestone."

Among Cœlenterate animals, the principal lime-makers are the true Corals (*Madreporaria*). Many of the limestones which enter into the composition of the crust of the earth, dating from the Ordovician period onwards, are more or less extensively composed of the skeletons of Corals. Though the Corals commonly occur in such a manner in the rock as to show clearly that they grew on the spot where the limestone was formed, it is questionable if any of the Palæozoic limestones can be properly said to be actual "coral-reefs," though some of the Devonian limestones of North America and Belgium may possibly be truly of this nature. In the Secondary and Tertiary periods, however, we meet with coralline limestones which may be considered as essentially similar in structure and mode of formation to the "coral-reefs" of the warm seas of the present epoch. The Corals, however, are not the only Cœlenterate animals which play an important part in the formation of limestones, for it is now known that certain of the *Hydrozoa* are likewise capable of giving rise to extensive calcareous deposits by the accumulation of their skeletons. Thus, certain of the Silurian and Devonian limestones are largely composed of the calcareous skeletons of the extinct *Hydrozoa* which constitute the group of the "Stromatoporoids." Other Palæozoic limestones are extensively made up of the remains of organisms like *Solenopora* and *Mitcheldeania*, which are possibly referable to the *Hydrozoa*. At the present day, the only *Hydrozoön* which is conspicuously concerned in the formation of limestone is the Hydrocoralline genus *Millepora*, which plays an important part in the construction of many of the existing "coral-reefs."

Of the *Echinodermata* there is only one order—viz., that of the Sea-lilies or *Crinoids*—which demands special mention in the present connection. At the present day, the Crinoids constitute a but feeble remnant of a once powerful and widely distributed group, and they are not known to exist anywhere in numbers sufficient to render them noteworthy as lime-makers. Among the older rocks of the earth's crust, however, and more particularly in deposits of Ordovician, Silurian, Devonian, and Carboniferous age, are found great beds of limestone, essentially composed of the broken stems and detached plates of Crinoids (fig. 7). Such limestones are known to geologists as "Crinoidal limestones" and "Encrinital marbles," and they are usually composed of more or less broken and rolled

fragments of Crinoids, showing that the materials of which they are composed had been subjected to the action of the sea before being consolidated into rock. In other cases, especially among some of the Crinoidal limestones of the Mesozoic period, the Crinoids seem to have grown on the spot where the limestone was deposited. Very generally, the Crinoidal fragments are sufficiently large and well preserved to be readily recognised, even with the unassisted eye; but even when they have been greatly abraded and worn down, their presence can usually be detected without difficulty by an examination of thin sections by means of the microscope. By this method it is, at any rate, almost always possible to determine whether or not a given fragment is Echinodermal, since the minute structure of the skeleton in the animals of this group is highly characteristic.



Fig. 7.—Section of Crinoidal limestone, from the Devonian (Hamilton Formation) of Canada, enlarged ten times. The matrix in which the Crinoidal fragments are enclosed, is mostly a fine calcareous mud. (Original.)

None of the members of the great series of the Annulose Animals can be said to play a very important part in the formation of limestones. Apart from the occasional presence in limestones of the calcareous cases of the Tubicolous Annelides, almost the only Annulose animals which ever contribute to lime-making are the *Crustacea*. In some cases, however, the calcareous crusts of certain groups of Crustaceans (particularly the Trilobites and the Ostracodes) constitute a noteworthy element in the composition of limestones.

On the other hand, the two existing groups of the Molluscoids—viz., the *Polyzoa* and the *Brachiopoda*, have both been extensively concerned in lime-making. In many of the Palæozoic limestones, the remains of *Polyzoa* constitute a conspicuous feature, though they cannot be said to form the bulk of the rock. In some of the Secondary and Tertiary limestones, however, the rock is really made up to a predominating extent of the calcareous skeletons of *Polyzoa*. Well-known examples of such so-called "Coralline limestones" are found in the Upper White Chalk of the continent of Europe, and in the "Coralline Crag" (Pliocene) of Suffolk and Norfolk. The Brachiopods, again, exerted their greatest activity as lime-makers during the Palæozoic period, many of the limestones of the Ordovician, Silurian, Devonian, and Carboniferous periods being

largely made up of the entire or fragmentary shells of animals belonging to this group.

Still more important are the true Molluscs, the shells of which have commonly been accumulated to form beds of limestone in all the great periods from the Ordovician onwards. Some of these "shell-limestones" are composed of the exuviæ of sedentary Molluscs, such as Oysters, and have therefore been formed in place. Excellent examples of such limestones are afforded by portions of the "Muschelkalk" of the Trias of Germany, and the massive "Hippurite limestone" of southern Europe. In other cases, the limestone is made up principally of the broken fragments of Molluscan shells which have been subjected to the transporting and abrading action of the sea; and the rock has therefore been formed in a manner similar to that in which the "shell-sand" of modern shores has been produced. In still other cases, again, the limestone has been formed by the slow accumulation on the sea-bottom of the shells of "pelagic" Molluscs, which live at or near the surface of the sea, and the skeletons of which fall to the bottom on the death of their owners. Of this nature are the "Pteropodal ooze" of the present period and the "Pteropodal limestones" associated with

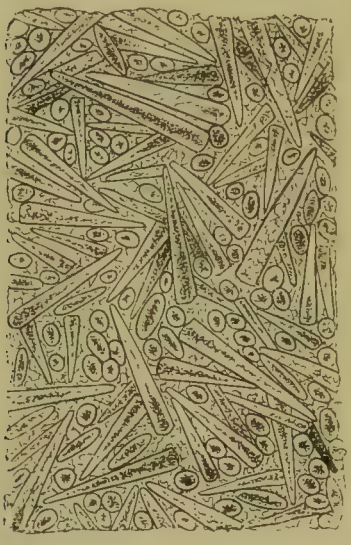


Fig. 8.—Section of a Pteropodal limestone, made up of the shells of *Styliola fissurella*, Hall, from the Devonian (Genesee Slates), Canandaigua, United States. Enlarged twenty times. (Original.)



Fig. 9.—Section of a Tertiary limestone ("Leitha-kalk"), from Nussdorf, near Vienna, composed almost entirely of fragments of Nullipores cemented together by a crystalline matrix. Enlarged three times. (Original.)

uplifted coral-reefs. Similar "Pteropodal limestones" are known to occur even in deposits as old as the Devonian (fig. 8), but they are of rare occurrence and are usually of small thickness. Lastly, it is to be noticed that limestones may be formed as well by fresh-

water Molluscs as by those which inhabit the sea. The recent "shell-marls" are examples of deposits of this nature, and various Tertiary and Secondary limestones are more or less extensively charged with the shells of fresh-water Gastropods and Bivalves.

Finally, it is to be noted that animals are not the exclusive agents concerned in the building up of limestones. Certain of the calcareous Algæ—such as the "Corallines," the "Nullipores," and the singular family of the *Dactyloporidæ*—are capable, singly or in combination with other organisms, of forming accumulations of lime, sometimes upon a most extensive scale. The two latter groups, in particular, have given rise to vast masses of limestone. Examples of the *Dactyloporidæ* occur even in the Palæozoic limestones, but the most famous and most extensive deposit formed by *Algæ* of this group is the well-known "Gyroporella-limestone" of the Bavarian and Tyrolese Alps, the age of which is Triassic. Limestones formed more or less largely of "Nullipores" (*Lithothamnion*) occur to some extent in the Secondary rocks, and are extensively developed in the Tertiary series. The most famous of these is the "Nulliporen-kalk" or "Leitha-kalk" of the Vienna basin (fig. 9), which attains a considerable thickness, and extends from Austria, through the Balkans, to Asia Minor and Persia.

In connection with the subject of the constitution of the ordinary organic limestones, the researches of Dr Sorby on the precise chemical composition of calcareous organisms demand a brief notice. The carbonate of lime in calcareous organisms exists sometimes in the condition of *aragonite*, sometimes in that of *calcite*. The chief differences between these two allotropic conditions of calcium carbonate are: (1) that calcite is optically uniaxial, whereas aragonite is biaxial; (2) that calcite has a specific gravity of about 2.72, whereas the density of aragonite is 2.93; and (3) that aragonite is harder than calcite, as shown by the fact that the former will scratch a crystal of Iceland spar along the line of the short diagonal of one of the crystalline facets, whereas the latter will not do so. In the second place, the composition of the skeleton of calcareous organisms varies in different groups, some having a skeleton wholly of calcite and others wholly of aragonite, while in some cases the skeleton is composed in part of calcite and in part of aragonite. The following table shows the principal variations in this respect, as determined by the researches of Sorby:—

1. *Foraminifera.*—The test of the calcareous *Foraminifera* appears to be in general composed of calcite, though a certain amount of aragonite seems to be sometimes present. [In the porcellanous *Foraminifera* the test is very probably wholly composed of aragonite.]

2. *Madreporaria.*—The true Corals have the skeleton composed, mainly or wholly, of aragonite.

3. *Alcyonaria.*—The skeleton of the Alcyonarian Corals is mainly of calcite, but with indications of the presence of a small amount of aragonite or phosphate of lime.

4. *Echinodermata.*—The skeleton is always composed essentially of calcite.

5. *Annelida.*—The skeleton seems to be always composed of calcite.

6. *Crustacea.*—The shell of the Crustaceans is mainly composed of calcite, with a variable intermixture of phosphate of lime.

7. *Polyzoa.*—The skeleton of the calcareous *Polyzoa* consists of a variable intermixture of calcite and aragonite, the two inseparably blended together.

8. *Brachiopoda.*—The shell appears to be always composed of calcite [sometimes with a considerable proportion of phosphate of lime].

9. *Lamellibranchiata.*—The shell of the Bivalve Molluscs is often composed wholly of aragonite, but in other cases (*e.g.*, Oysters and Scallops) it is wholly of calcite, while in others (*e.g.*, in Mussels, *Pinna*, &c.) the shell has an outer layer of calcite and an inner layer of aragonite.

10. *Gastropoda.*—Most Univalve Molluscs have the shell wholly composed of aragonite, but some (such as *Patella*, *Fusus*, *Littorina*, and *Purpura*) possess an outer layer of calcite and an inner layer of aragonite.

11. *Cephalopoda.*—The shells of Cephalopods appear to be mainly composed of aragonite.

The above-mentioned variations in the chemical composition of the skeleton of calcareous organisms have been shown by Sorby to be associated with important differences as to the condition of preservation of these skeletons as fossils. It has been shown, namely, that aragonite is relatively much less *stable* than calcite. Calcite has no tendency, under any natural circumstances, to pass into the condition of aragonite ; aragonite very readily passes into the condition of calcite. Hence in the processes connected with fossilisation, calcareous skeletons composed of aragonite are much more liable to undergo alteration, replacement, or even dissolution, than are those composed of the more stable calcite. It is for this reason that the shells of Gastropods and Lamellibranchs—which are commonly composed entirely of aragonite—are so often found as fossils in the condition of mere "casts," the original shell having been wholly removed by solution, or having been replaced by a pseudomorph composed of irregularly placed (unoriented) crystals of calcite. For the same reason, in cases where the shell consists in part of aragonite and in part of calcite, it is common for the aragonite layer to have been removed, while the calcite layer has been preserved.

Before leaving the subject of limestones, it may be advisable to notice briefly the more important differences as regards chemical constitution or minute structure which give rise to special types of limestone, and which not infrequently have a palæontological significance. The differences here specially alluded to may be considered under the following heads :—

(1.) *Lithological Nature.*—Many of the differences which distinguish particular varieties of limestone concern simply the mineral nature of the rock, and are of no special importance from a palæontological point of view. Thus, many limestones are more or less extensively made up of angular quartz-grains embedded in a matrix of crystalline calcite (fig. 2, B), the rock becoming an *arenaceous* limestone. There are innumerable links, in fact, between what may be called a "calcareous sandstone" and a true "limestone" containing

a small number of scattered grains of quartz. In other cases more or less silicate of alumina is present, and the rock becomes an *argillaceous* limestone, passing, in extreme cases, into a "calcareous shale." In other cases, again, the limestone may be more or less highly charged with minute particles of carbon, or may be more or less impregnated with certain hydrocarbons, the rock becoming a *carbonaceous* limestone or a *bituminous* limestone, as the case may be. The term "marble" is one of no very precise signification, any limestone which is sufficiently hard and compact to take a high polish being usually spoken of under this name. "Chalk," again, from a purely lithological point of view, is a soft pulverulent limestone, but it is occasionally quite hard and compact; and its truly essential characters depend upon its organic structure, which will be more fully considered later on.

(2.) *Chemical Constitution.*—The most important variation in limestones, from a chemical point of view, is established by the presence in the rock of more or less carbonate of magnesia. The presence of a certain amount of magnesia in a limestone is a very common phenomenon, and often only admits of detection by means of chemical analysis. Limestones which contain a variable and comparatively small amount of carbonate of magnesia are spoken of as "magnesian limestones," and they often differ little or not at all from ordinary limestones in either appearance or structure. Where there is a notable proportion of carbonate of magnesia present, the limestone often assumes a brownish or yellowish colour, with a sandy aspect, while it shows a marked tendency to undergo secondary crystallisation. This is shown in some cases by the development of a concretionary structure in the rock, the so-called "concretions" being truly the result of an imperfect form of crystallisation. Thin sections, also, of such magnesian limestones invariably show that the rock has undergone more or less extensive recrystallisation, subsequent to consolidation; and the organic fragments originally present in the rock have been thereby more or less largely obscured, or, it may be, completely obliterated. Owing, further, to the comparative insolubility in water of carbonate of magnesia as compared with carbonate of lime, the larger calcareous organisms (such as the shells of Molluscs) in the more highly magnesian limestones have been commonly dissolved out of the rock, and are now only represented by casts and moulds. Where the carbonate of magnesia is present in a limestone in such quantity as to form with the carbonate of lime a true double carbonate, the rock is what is strictly called a "dolomite." The true dolomites, when examined microscopically, are always found to be more or less intensely crystalline. In some cases the recrystallisation to which the rock has been subjected subsequent to its original formation has not been

sufficient to absolutely destroy any organic remains present in the rock. Thus, in the dolomites of the Guelph formation (Silurian) of Canada, the presence of fossils can commonly be recognised in thin sections, though these have always undergone more or less secondary change, and have usually been replaced by calcite or by peroxide of iron, or are represented simply by vacant spaces in the rock. On the other hand, in many dolomites (fig. 10) secondary crystallisation has been as complete as in statuary marble, and any organic remains which may have existed in the rock to begin with have been totally obliterated.

With regard to the origin of magnesian limestones, it is sufficient here to say that those in which magnesia is present in comparatively small quantity probably owe their peculiarities to the conditions under which they were originally deposited; and there are even true dolomites in which there is ground for thinking that the rock was



Fig. 10.—Thin section of dolomite, from Sweden, enlarged ten times. The rock is an aggregate of comparatively large crystals, which exhibit the characteristic cleavage-lines of carbonate of lime. (Original.)



Fig. 11.—Section of oolitic limestone, Carboniferous, Kershope Foot, enlarged thirty times. Some of the spheroids have no definite boundaries, and consist simply of diffuse radiating crystallisations. (Original.)

magnesian from the first. In other cases, again, it cannot be doubted that the rock was originally a normal limestone, and that "dolomitisation" was the result of secondary changes affecting the rock subsequent to its original formation.

(3.) *Minute Structure.*—The most important of the ordinary structural peculiarities of limestones is what is known as the "*oolitic*" structure. The subject of the oolitic structure of calcareous rocks is one of great complexity, and the morphological differences which exist between different oolites are very numerous and highly remark-

able. It will not, therefore, be possible here to do more than glance at some of the more salient peculiarities presented by oolitic limestones. If a thin slice of any ordinary oolitic limestone be examined under the microscope, it will be found to exhibit more or less numerous rounded or oval grains, of variable size, embedded in a matrix of crystalline calcite (fig. 11). Each oolitic grain, or spheroid, ordinarily exhibits a more or less obvious structure out of concentrically superimposed layers, each layer being composed of minute crystals of calcite arranged in a radiating manner, with their long axes perpendicular to the surface. Very commonly there may be detected in the centre of the grain a larger or smaller foreign body, such as a grain of quartz or a fragment of some calcareous organism, which has served as a nucleus round which the spheroid has been built up. In other cases, no traces of a foreign nucleus can be recognised. According to the view usually entertained, oolitic grains of the type just described have been produced by "the original deposition of calcite round nuclei gently drifted along by currents of the ordinary temperature, which caught up more or less of the surrounding mechanical impurities" (Sorby). According to this view, therefore, the rock was primitively a loosely compacted aggregate of oolitic grains, along with entire or fragmentary calcareous organisms, and solidification was a secondary process, due to the percolation through the mass of water charged with carbonate of lime in solution, and the consequent precipitation of crystalline calcite in all the vacant spaces between the grains. This view, doubtless, affords an adequate explanation of the formation of the ordinary oolitic limestones. There are, however, cases in which it would rather seem that the formation of the oolitic grains has been due to secondary crystallisation in an originally normal limestone. Thus, in certain limestones some of the oolitic grains have no definite boundaries, but consist simply of diffuse radiate crystallisations, which may or may not have a central nucleus for their starting-point (fig. 11). The structure just alluded to must, however, be carefully distinguished from cases in which the oolitic grains have undergone recrystallisation at some period posterior to their original formation. In this latter case, the grains preserve their outlines, but the primitive radiate and concentric structure is more or less completely destroyed, and the spheroids consist simply of irregularly placed crystals of comparatively large size.

In all the fossiliferous formations, from the Ordovician onwards, oolitic limestones are of common occurrence; but they vary considerably in their more minute characters. In one of the commonest varieties of oolitic limestones the grains assume a greatly elongated form, when the name of "spheroids" is hardly applicable to them. Such elongated grains have been sometimes regarded as owing their

shape to pressure, but it does not appear that this is an adequate explanation, and their mode of origin is still obscure.

(4.) *Superinduced Structure.*—There are probably no limestones, including even those now actually in process of formation, which are absolutely free from superinduced structural peculiarities of one kind or another. In a general way, these superinduced peculiarities depend upon a more or less extensive recrystallisation of portions of the rock, it being sometimes the matrix of the limestone which is thus affected, sometimes the included fragments, and sometimes both. In many cases, the secondary crystallisation of a limestone may be the result of slow chemical or physical changes, connected in the main with the percolation through the rock of water holding carbonic acid or other ingredients in solution. As regards the organic fragments present in most limestones, these gradual changes are doubtless much facilitated by the readiness with which aragonite passes into the condition of calcite. As a general rule, however, these slow alterations do not affect the structure of the limestone so profoundly but that the original constitution of the rock is easily recognisable by suitable methods of examination. In many cases, on the other hand, and especially among the older limestones of the earth's crust, the rock has undergone changes of a much deeper and more far-reaching character than those above alluded to. The most prominent of these changes consists in a more or less complete crystallisation of the rock, leading to a more or less complete obliteration of any fossils which it may have contained. The general causes which contribute to bring about this thorough crystallisation of limestones are heat and pressure, singly or together, combined with the action of percolating water, which is rendered chemically potent by having certain substances dissolved in it.

That the application of a powerful heat to limestone will cause its crystallisation is sufficiently exemplified by the well-known phenomena observable in a limestone when intersected by an intrusive igneous rock. Thus, limestone in the immediate neighbourhood of a trap-dyke or a mass of granite is found to have been converted into a crystalline marble, in which, as a rule, no traces of organic structure can be detected under the microscope. When developed upon a larger scale, crystalline limestones are usually found in regions which can be shown to have been subjected to powerful earth-movements, one result of which must have been the application to the rocks of the region of intense pressure. Usually greater or less elevation of temperature has co-operated with the pressure in producing alterations in the structure of the rocks affected by these movements. Speaking generally, therefore, we may regard the "regional" crystallisation of limestones as due to the application of great pressure to deeply buried masses of these rocks, raised to a

moderately high temperature and impregnated with water holding more or less powerful chemical agents in solution.

The initial stages of the changes above alluded to can be well observed in many of the older limestones, where the rock has been subjected to sufficient pressure to produce crushing and cleavage, but where crystallisation has been imperfectly or not at all induced. Some of such limestones show plain signs of intense pressure in the distortion and partial destruction of their contained organic fragments, as seen in microscopic sections, at the same time that the mass of the rock has remained free from crystallisation. In other cases, as in some of the Devonian limestones of Devonshire, not only are the organic remains in the rock more or less distorted by pressure, but they have usually undergone recrystallisation, though this has not been sufficiently intense to render them unrecognisable. The complete development of the changes here in question is seen in statuary marble and in the "metamorphic" limestones generally, where a microscopic examination of the rock shows it to be a mere aggregate of variously-sized crystals of carbonate of lime (or, in the case of dolomites, of the double carbonate of lime and magnesia), all traces of organic structure being entirely obliterated (fig. 10). In some instances (as, for example, in the case of the white statuary marble of Carrara) it can be shown that such a purely crystalline limestone was, to begin with, a quite normal limestone, which was in part caught up in the folds of a mountain-chain, and thus subjected locally to enormous pressure. In other cases, we have evidence that a whole region has been subjected to powerful earth-movements, the pressure evolved in which has been so intense and so widely diffused that no part of the original limestone has preserved its primary organic structure. In such cases—as, for example, in the crystalline limestones of the Highlands—adventitious minerals, such as serpentine, are commonly developed in the rock, showing that active chemical changes have accompanied the mechanical pressure to which the rock has been subjected. We must not, however, lose sight of the possibility that the "metamorphic" limestones of the Archæan period (such as the Laurentian limestones of Canada) *may* owe their crystalline character and their mineral peculiarities, not to alteration subsequent to deposition, but to the conditions under which they were originally formed. It is also to be remembered that in some cases we meet with beds of granular and crystalline limestone intercalated in a series of more or less completely normal limestones, without there being any obvious reason for the difference. In such cases, it is probable that the entire series of deposits has been subjected to pressure, and that, owing to slight peculiarities in mineral or chemical constitution, certain bands have undergone crystallisation, while others have escaped with nothing more than a certain

degree of induration. Indeed, even in a single hand-specimen, it is not unusual to find that some portions of the rock have undergone complete secondary crystallisation, while others are comparatively unchanged.

Siliceous Organic Rocks.—We have seen that the *calcareous* or lime-containing rocks are the most important group of organic deposits, while the *siliceous* or flint-containing rocks may be regarded as the most important, most typical, and most generally distributed of the mechanically formed deposits. We have, however, now briefly to consider certain deposits which are more or less completely formed of flint, but which nevertheless are essentially organic in their origin.

Silica is probably invariably held in solution in small quantity in natural waters, whether these be fresh or salt. Small as is the quantity of silica dissolved by rivers or by the sea, there is sufficient of it to supply material for the flinty skeletons of innumerable organisms, both animal and vegetable; and the accumulation of such skeletons may, under favourable conditions, give rise to very considerable deposits of siliceous matter. The two principal groups of animals which secrete a siliceous skeleton, and may thus produce deposits of silica, are certain forms of the Sponges and the minute organisms known as the *Polycystina*. In a very large number of Sponges, the skeleton consists of variously shaped needles or "spicules" of flint, sometimes detached and entirely separate, at other times more or less closely united with one another. The accumulation of these spicules at the bottom of the sea may give rise to extensive siliceous deposits, such as have been described by Dr Hinde as occurring in the Lower and Upper Greensand of Britain. In some cases the skeletal structures of Sponges which have been accumulated to form deposits such as those above alluded to, have undergone comparatively little change, and their presence can be readily recognised. In other cases, however, these siliceous structures have undergone much alteration, and their existence cannot be demonstrated without difficulty. It is known, namely, that there is a marked difference as regards relative solubility in water between ordinary crystalline *quartz*, on the one hand, and the peculiar form of silica which occurs in the skeletons of animals and plants, on the other hand. Quartz is relatively a very stable substance, and it is only in highly heated waters, containing in solution such ingredients as the alkaline carbonates (as, for example, in the waters of certain hot springs), that quartz is ever found to be dissolved in large quantity. On the other hand, the silica which forms the skeleton of flint-secreting animals and plants exists under a peculiar modification —as "amorphous" or "colloidal" silica—which is comparatively unstable, and, under suitable conditions, freely soluble in water. Hence, siliceous deposits formed by the accumulation of the flinty

skeletons of animals and plants are very liable to be affected by secondary changes, chiefly due to the percolation of water throughout their mass. As the main result of these changes, the siliceous skeletons become more or less extensively dissolved, the percolating water becoming thus charged with a larger or smaller amount of silica in solution. This dissolved silica is ultimately redeposited in the solid form, having, however, now lost its organic structure. By this partial solution of the skeletons of siliceous organisms, and the subsequent precipitation of the dissolved silica thus obtained, we may explain the common presence of nodules or beds of "flint" or "chert" in many of the great geological formations. This subject will, however, be treated of in greater detail in connection with the palæontological history of the Sponges.

The *Polycystina* are minute organisms belonging to the *Protozoa*, and nearly related to the *Foraminifera*, from which they differ, among other characters, by the fact that they secrete a "test" or skeleton of flint instead of one composed of lime. The *Polycystina* have a wide distribution in our present seas, and their skeletons are very generally recognisable, in greater or less numbers, in the deep-sea muds of the great oceans, being easily recognised by their exquisite shape, their glassy transparency, the general presence of longer or shorter spines, and the sieve-like perforations in their walls. In many places, in fact, especially in the colder portions of the great oceans, or at very great depths, the "Globigerina ooze" disappears, and its place is taken by a "Radiolarian ooze" composed almost wholly of the shells of *Polycystina*. Similar deposits, made up of the flinty skeletons of these Radiolarians, have been formed at previous periods of the earth's history, and now form part of the earth's crust. The two most famous of these deposits occur in Barbados and in the Nicobar Islands, the former being well known to workers with the microscope as the "Barbados earth" (fig. 12).

In addition to flint-producing animals, we have also the great group of fresh-water and marine microscopic plants known as *Diatoms*, which likewise secrete a siliceous skeleton, often of great beauty. The skeletons of Diatoms are found abundantly at the present day in lake-deposits, guano, the silt of estuaries, and in the mud which covers many parts of the sea-bottom; they have been detected in strata of great age; and in spite of their microscopic dimensions, they have not uncommonly accumulated to form deposits of great thickness, and of considerable superficial extent. Thus the celebrated deposit of "tripoli" ("Polir-schiefer") of Bohemia, largely worked as polishing-powder, is composed wholly, or almost wholly, of the flinty cases of Diatoms, of which it is calculated that no less than forty-one thousand millions go to make up a single cubic inch of stone. Another celebrated deposit is the so-

called "Infusorial earth" of Richmond in Virginia (fig. 13), where there is a stratum, in places thirty feet thick, composed almost entirely of the microscopic shells of Diatoms.

In addition to deposits formed of flint itself, there are other siliceous deposits formed by certain *silicates*, and also of organic



Fig. 12.—Shells of *Polycystina* from "Barbados earth"; greatly magnified. (Original.)



Fig. 13.—Cases of Diatoms in the Richmond "Infusorial earth"; highly magnified. (Original.)

origin. It has been shown, namely—by observations carried out in our present seas—that the shells of *Foraminifera* are liable to become completely infiltrated by silicates (such as "glauconite," or silicate of iron and potash). Should the actual calcareous shell become dissolved away subsequent to this infiltration—as is also liable to occur—then, in place of the shells of the *Foraminifera*, we get a corresponding number of green sandy grains of glauconite, each grain being the *cast* of a single shell. It has thus been shown by Dr W. B. Carpenter that the green sand found covering the sea-bottom in certain localities (as found by the Challenger expedition along the line of the Agulhas current) is really organic, and is composed of casts of the shells of *Foraminifera*. Long before these observations had been made, it had been shown by Professor Ehrenberg that the green sands of various geological formations are often composed in part of the internal casts of the shells of *Foraminifera*; and we have thus another and a very interesting example how rock-deposits of considerable extent and of geological importance can be built up by the operation of the minutest living beings.

Carbonaceous Deposits.—It only remains in connection with the general subject of the organically formed rocks to shortly consider the rock-deposits in which *carbon* is found to be present in greater or less quantity. In the great majority of cases where rocks are found to contain carbon or carbonaceous matter, it can be stated with certainty that this substance is of organic origin, though it is

not necessarily derived from vegetables. Carbon derived from the decomposition of animal bodies is not uncommon; though it never occurs in such quantity from this source as it may do when it is derived from plants. Thus, many limestones are more or less highly bituminous; the celebrated siliceous flags or so-called "bituminous schists" of Caithness are impregnated with oily matter apparently derived from the decomposition of the numerous fishes embedded in them; Silurian shales containing Graptolites, but destitute of plants, are not uncommonly "anthracitic," and contain a small percentage of carbon derived from the decay of these zoophytes; whilst the petroleum so largely worked in North America has not improbably an animal origin. That the fatty compounds present in animal bodies should more or less extensively impregnate fossiliferous rock-masses, is only what might be expected; but the great bulk of the carbon which exists stored up in the earth's crust is derived from plants; and the form in which it principally presents itself is that of *coal*. We shall have to speak again, and at greater length, of coal, and it is sufficient to say here that all the true coals, anthracites, and lignites, are of organic origin, and consist principally of the remains of plants in a more or less altered condition. The bituminous shales which are found so commonly associated with beds of coal, also derive their carbon primarily from plants; and the same is certainly, or probably, the case with similar shales which are known to occur in formations younger than the Carboniferous. Lastly, carbon may occur as a conspicuous constituent of rock-masses in the form of *graphite* or *black-lead*. In this form it occurs in the shape of detached scales, or of veins or strings, or sometimes of regular layers; and there can be little doubt that in some instances it has an organic origin, though this is not capable of direct proof. When present, at any rate, in quantity, and in the form of layers associated with stratified rocks, as is sometimes the case in the Laurentian formation, there seems to be considerable probability in the hypothesis which would regard it as primarily of organic origin and as of the nature of an altered coal.

CHAPTER III.

SUCCESSION OF FORMATIONS—CONTEMPORANEITY OF STRATA—GEOLOGICAL CONTINUITY.

Different Ages of the Aqueous Rocks.

The two principal tests by which the age of any particular bed, or group of beds, may be determined, are superposition and organic remains—a third test being sometimes afforded by mineral characters. The first and most obvious test of the age of any aqueous rock is its relative position to other rocks. Any bed or set of beds of sedimentary origin is obviously and necessarily older than all the strata which surmount it, and younger than all those upon which it rests. It is to be remembered, however, that superposition can at best give us but the *relative* age of a bed as compared with other beds of the same region. It cannot give us the *absolute* age of any bed; and if we are ignorant of the age of any of the beds with which we may be dealing, we have to appeal to other tests to learn more than the mere order of succession in the particular region under examination. Moreover, deposits formed in isolated basins, and not in an area of continuous sedimentation, have necessarily no stratigraphical relations to deposits laid down in other areas, and their age can only be determined by palæontological tests. This difficulty, as pointed out by Professor C. A. White, is enhanced when such isolated sediments have been produced within inland *fresh* waters; since such sediments, from their mode of formation, can have no place in any observed order of superposition of *marine* deposits, and would, in addition, necessarily contain wholly different fossils as compared with beds laid down in the sea.

The second, and in the long-run more valuable, test of the age of the different sedimentary beds, is that afforded by their organic remains. Still, this test is also by no means universally applicable, nor in all cases absolutely conclusive. Many aqueous rocks are unfossiliferous through a thickness of hundreds, or even thousands,

of feet of little altered sediments; and even amongst beds which do contain fossils, we often meet with strata of a few feet or yards in thickness, which are wholly destitute of any traces of life. Many fossils, again, range vertically through many groups of strata, and in some cases even through several formations. Such fossils, therefore, if occurring by themselves, or considered apart from other associated organisms, are not conclusive as to the age of any particular set of beds. As the result, however, of combined palæontological and geological researches, it is now possible for us to divide the entire series of stratified deposits in any given region into a number of definite rock-groups or formations, each of which is characterised by possessing an assemblage of organic remains which do not occur in association in any other formation. Such an assemblage of fossils, characteristic of any given formation, represents the *life* of the particular period in which the formation was deposited. It follows from this, that whenever we can get a group or collection of fossils from any particular bed or set of beds, there is rarely any difficulty in determining, as regards the particular region under examination, the precise geological horizon of the beds in which the fossils occur.

With certain limitations, however, we may go much further than this. Not only are the great formations characterised by special and characteristic assemblages of animals and plants; but, in a general way, each subdivision of each formation has its own peculiar fossils, by which it may be recognised by a skilled worker in palæontology. Whenever, for instance, we meet in Britain with the fossils known as Graptolites, we may be sure that we are dealing with Cambrian, Ordovician, or Silurian rocks. We may, however, go much further than this. If the Graptolites belong to certain genera, we may be sure that we are dealing with Ordovician rocks. Furthermore, if certain special forms are present, we may be even able to say to what exact part or subdivision of the Ordovician series they belong.

All these conclusions, however, would have to be accompanied by a tacit but well-understood reservation. No Graptolites have ever been found in Britain out of rocks known upon other grounds to belong to one or other of the three formations above mentioned; but there is no reason why they might not at any time be found in younger deposits. In the same way, the species and genera which we now regard as characteristic of the Ordovician, might at any time be found to have survived into the Silurian period. We should never forget, therefore, in determining the age of a rock by palæontological evidence only, that we are always reasoning upon generalisations which are the result of experience alone, and which may at any time be overthrown by fresh discoveries.

There is, moreover, another important principle to take into

account in considering the value of fossils as tests of the age of strata. Within a given area of such dimensions that we may suppose it to have formed a single life-province, we shall undoubtedly find that there is a recognisable succession of life-forms, so that particular groups of rocks may be safely assigned, on the strength of their contained fossils, to fixed places in the geological series, and a definite chronological succession of the strata may thus be established *for the region examined.* When we come, however, to compare together the successive life-forms of widely remote areas, which must be supposed to have always belonged to different life-provinces, we cannot expect to find anything like a *precise* identity. We shall probably be able to establish a *general* correspondence or analogy, sufficient to establish a general parallelism of the successive groups of strata in the two regions compared; but it can only be in exceptional circumstances that the fauna of a particular series of beds in one region can possibly be largely identical with that of a coeval series in a widely distant region. This principle is sufficiently established by the simple consideration that the assemblages of animals now existing simultaneously in different regions are so unlike each other that we can by their means divide the earth's surface into a number of definitely bounded "zoological provinces," and that there is every reason to suppose that similar life-provinces have existed in all the great geological periods of which the palæontological history has been preserved. If, on the other hand, we were to find that the rocks deposited in any particular period of the earth's history contained absolutely identical fossils in all parts of the world, we should be forced to conclude that during that period there were no "zoological provinces" developed, but that the entire terrestrial surface constituted a single vast life-province inhabited by the same kinds of animals and plants. Nothing that we have of actual evidence, derived either from the past or the present, would, however, support such a supposition; but this point will be more clearly brought out in dealing with the "contemporaneity" of strata in different regions.

General Chronological Succession of the Stratified Rocks.

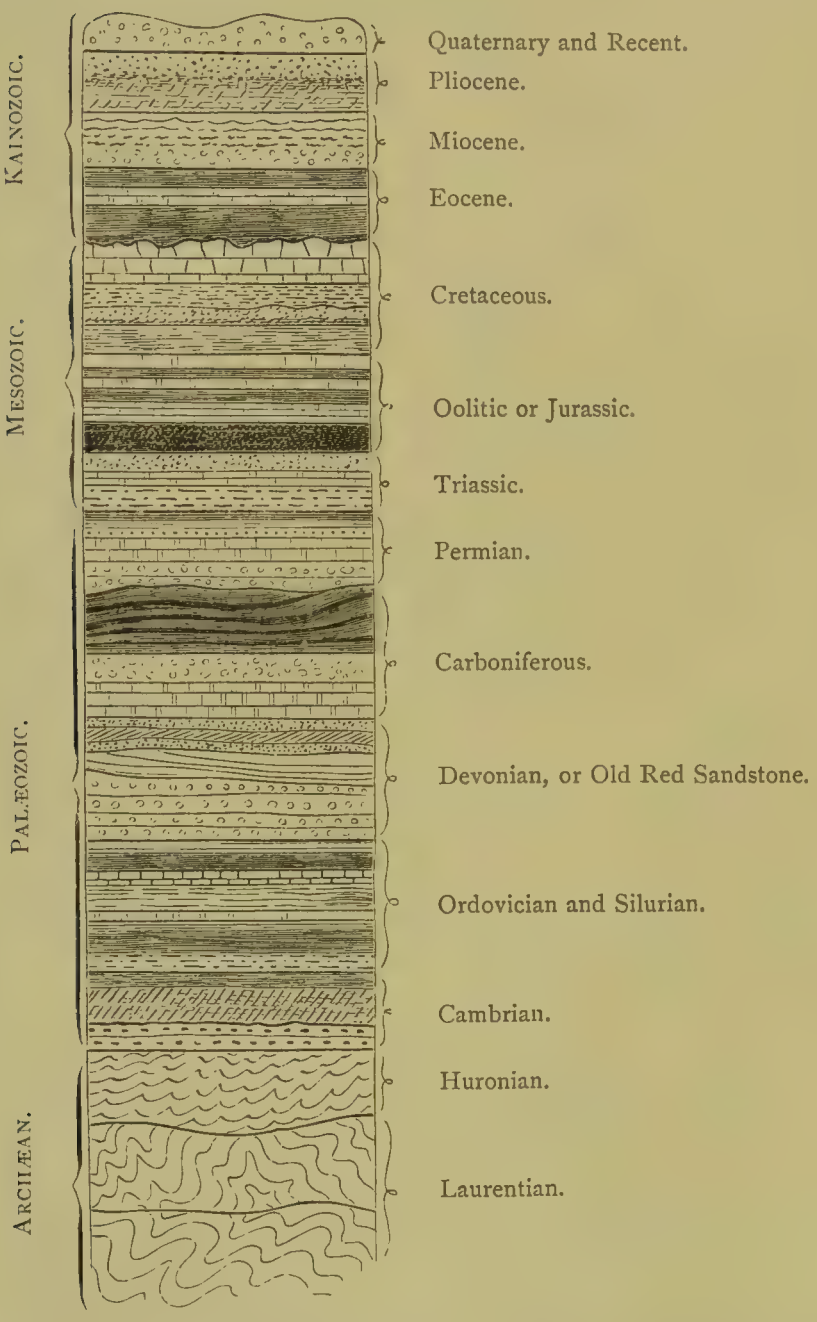
As the result of observations made upon the superposition of rocks in different regions, from their mineral characters, and from their included fossils, geologists have been able to divide the series of the stratified rocks into a number of different divisions or "rock-systems," each characterised, in any given region, by a *general* uniformity of mineral composition and by a special and peculiar *assemblage of life-forms*, and each representing a "period" in the earth's history. In every country in the world that has been geo-

logically investigated, such a chronological succession of the stratified rocks has been established, but the order of succession is not necessarily identical even in regions geographically close together. On the contrary, as above pointed out, a comparison of the succession of the stratified deposits in two regions widely remote from one another in space will show that, though a general parallelism will exist, the corresponding rock-groups in the two regions will not contain absolutely identical fossils, and that certain rock-groups which are present in one region are absent in the other. In no one region, therefore, do we meet with an absolutely complete and continuous succession of stratified rock-groups, nor could such ever have been laid down except in a region which had been continuously beneath the sea and constantly the seat of sedimentation since the beginning of geological time. At all times of which we have geological record, the earth's surface has, however, consisted partly of dry land and partly of sea, and the terrestrial and marine areas have simply undergone displacement and have been changed in position from time to time. During each successive epoch, therefore, certain areas have been the seat of sedimentation, while others have been dry land; but the dry land of one period may become the sea of the next, and *vice versâ*, and sedimentation is thus transferred in the course of ages from one place to another. Hence when we meet with a stratified deposit in one region (A) which has no representative in an adjoining region (B), we know that one or other of two things has occurred. In the first place, B may have been dry land while A was beneath the ocean. In that case, the missing deposit was never laid down in B at all. Or, in the second place, both of the areas may have been under the sea simultaneously, and the deposit in question may have been originally laid down in both; but A may have remained continuously under water, while B may have been elevated to form dry land, undergoing in process of elevation sufficient denudation to destroy the deposit in question.

By a comparison of many different areas, geologists have been enabled to frame a *general order of succession of the stratified rocks*, which, though based originally upon the facts observed in Europe, is nevertheless, *in its main outlines*, applicable to other and widely distant regions. This general succession is diagrammatically shown in the annexed ideal section of the crust of the earth. The most ancient of all the stratified rocks are more or less intensely crystalline in character, and no undoubted fossils have hitherto been detected in them. They are grouped together under the general name of the *Archæan* rocks, and comprise several rock-systems, of which the best established is the Laurentian series of North America and of Europe. All the rock-groups above the Archæan are more or less richly fossiliferous, and are divided into three main "groups," each com-

IDEAL SECTION OF THE CRUST OF THE EARTH.

FIG. 14.



prising several smaller divisions or "systems." The oldest group comprises the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian "systems," which are spoken of as the *Primary*

or *Palæozoic* rocks (Gr. *palaios*, ancient ; *zoe*, life), because of the wide divergence of their animals and plants from any now existing upon the globe. The Triassic, Jurassic, and Cretaceous systems are grouped together as the *Secondary* or *Mesozoic* formations (Gr. *mesos*, intermediate ; *zoe*, life), because their organic remains are intermediate between those of the Palæozoic period, and those of more modern strata. The Eocene, Miocene, Pliocene, and Pleistocene rocks are grouped together under the head of *Tertiary* or *Kainozoic* rocks (Gr. *kainos*, new ; *zoe*, life), because the fossil animals and plants which they contain approximate in character to those now existing upon the globe.

According to the recommendations of the International Geological Congress, the following names should be employed for the larger and smaller divisions of the stratified rocks and the time-divisions to which these correspond, the terms being arranged in order of their comprehensiveness.

Divisions of sedimentary formations ("*terranes*").	*Corresponding chronological terms.*
Group.	Era.
System.	Period.
Series (or *Section*).	Epoch.
Stage (or *Beds*).	Age.

The term "formation," very commonly employed by British geologists, is perhaps best retained as a loose general term to indicate any set of beds, large or small, which have some common characteristic, either as to mineral nature or fossil contents, or as to the mode in which the deposit has been formed. If used in a *definite* sense, it should be employed with reference to the mode of formation or the lithological nature of the rocks ; so that we may suitably speak of the "Chalk Formation," or the "Coal Formation," or of a "marine formation," or a "lacustrine formation."

The following table exhibits the great geological "systems," as developed in Europe, in chronological order, beginning with the youngest, the more important and typical British representatives of each being likewise mentioned :—

GENERAL CLASSIFICATION OF POST-ARCHÆAN FOSSILIFEROUS DEPOSITS.

KAINOZOIC OR TERTIARY GROUP.

1. RECENT FORMATIONS.—Deposits now in process of formation in seas, rivers, and lakes, and on land, such as the sands and muds of shallow seas, modern calcareous deposits like shell-beds, coral-reefs, &c., deep-sea muds, shell-marls, river-gravels, peat-mosses, &c.
2. QUATERNARY OR PLEISTOCENE FORMATIONS.—Post-glacial, Glacial, and Pre-glacial deposits, in which the Molluscs belong to existing species, but some of the Mammals are referable to extinct forms. Often grouped with the preceding under the general name of the "Post-tertiary deposits."

Kainozoic or Tertiary Group.

3. Pliocene System.—(British representatives, the Norwich Crag, and the Red and White Crags of Suffolk.)
4. Miocene System.—(The Upper Miocene or "Falunian" series and the Middle Miocene or "Mayencian" series are wanting or doubtfully represented in Britain. The Lower Miocene series is often grouped with the Upper Eocene series as a separate system, under the name of *Oligocene*, represented in Britain by the Hempstead, Bembridge, Osborne, and Headon beds.)
5. Eocene System.—(British representatives, the Barton Clay, Bagshot and Bracklesham beds, London Clay, Thanet Sands, &c.)

Mesozoic or Secondary Group.

6. Cretaceous System.—(British representatives, the Chalk, the Upper Greensand, the Gault, the Lower Greensand, and the Wealden Clays and Hastings Sand. The Lower Greensand and Wealden series are commonly grouped together as the "Neocomian" series.)
7. Jurassic System.—(British representatives, the Purbeck beds, Portland beds, Kimeridge Clay, Coral Rag, Oxford Clay, Cornbrash and Forest Marble, Great Oolite, Stonesfield Slate, Fuller's Earth, Inferior Oolite, and Lias.)
8. Triassic System.—(The uppermost Triassic or "Rhætic" beds are feebly represented in Britain by the Penarth beds and White Lias, and the "Keuper" and "Bunter Sandstein" of the continent of Europe have corresponding British representatives. The great marine division of the "Muschelkalk," which is largely represented in the Trias of Germany, is not developed in Britain.)

Palæozoic Group.

9. Dyas or Permian System.—(The deposits included under this name are more extensively developed in the European area than they are known to be in any other region, and it is doubtful if they can be regarded as a distinct "system." The chief British representatives of the Permian rocks are the Marl-slate and Magnesian Limestone, or "Zechstein," and the Penrith Sandstones or "Rothtodtliegendes.")
10. Carboniferous System.—(British representatives, the Coal-measures, the Millstone Grit series; the Yoredale series, the Scar-limestone series, and the Tuedian or Cement-limestone series.)
11. Devonian System.—(The Devonian rocks of Devonshire are marine, and contain representatives of the Lower, Middle, and Upper Devonian of the continent of Europe. The Old Red Sandstone of Scotland and of South-Western England and Wales was perhaps deposited in inland waters.)
12. Silurian System.—(British representatives, the Ludlow series, Wenlock series, and May Hill series.)
13. Ordovician System.—(British representatives, the Bala series, the Llandeilo series, and the Arenig series.)
14. Cambrian System.—(British representatives, the Tremadoc series, the Lingula Flag series, the Menevian series, and the Harlech series.)

Palæontological Evidence in Stratigraphical Geology.

As regards the division of the entire series of stratified deposits into the above enumerated primary "systems," the value of palæontological evidence has never been disputed. In any given country, it would be possible, undoubtedly, to determine the order and relative succession of the great formations, to some extent at any rate, by a mere appeal to the mineral character and order of superposition of the rocks themselves; but it is perfectly clear that this method of procedure would necessarily break down totally the moment we came to try and determine which were the corresponding formations in some far-distant region. By the stratigraphical evidence alone we could determine the relative position and age, for example, of the Silurian, Devonian, and Carboniferous systems in Britain; but it would be an entire impossibility to identify these same systems, say in North America, except by means of the fossils which they contain. So far, then, as this goes, no question has ever been raised as to the value and powers of Palæontology; but when we come to consider the minor rock-groups included in these systems, we find much difference of opinion as to the extent to which the evidence of the fossils is available in determining stratigraphical horizons. Part of this difference of opinion is due to imperfect acquaintance on the part of stratigraphical geologists with the methods of palæontological inquiry, and needs no discussion here; but part is well founded, and either arises from actual defects in the modes of research employed by palæontologists, or is due to the fact that the conditions under which different systems, or different portions of the same system, have been deposited have not been identical, and that conclusions which might be well founded in one case might be found to break down in another apparently similar case. To both of these points a brief consideration may be given.

As regards imperfections in the methods of palæontological research, by far the most important arises from the fact that too much weight has been attached by observers, especially in the earlier periods of the science, to the *age* of the rocks in which any given fossil occurred. So long as the opinion was current that fossils occurring in different formations were necessarily different, it followed of necessity that the smallest and most trivial varietal, or even individual, peculiarities of form or structure were considered as sufficient to establish specific distinction. At present, however, palæontologists are tolerably agreed that the mere fact of a difference of physical position, and consequently of age, ought not to be taken into account in considering the true affinities and systematic position of a fossil. At the same time it is, for many reasons, most important that palæontologists should have a general personal acquaintance

with the rocks in which occur any fossils that they may have to examine and describe; and many errors have arisen from the neglect of this sound rule.

Again, it is now clearly recognised that in any comparison between two sets of beds by means of their fossils, with a view of ascertaining their relative age, it is essential to take into account *the conditions under which the deposits in question were formed.* Thus, two marine deposits, both accumulated in shallow water, can be fairly and fully compared with one another, but they can only be imperfectly compared with a deposit formed in a deep sea, and they cannot be compared at all with deposits which have been formed in inland fresh waters or on land. Hence we find that palæontologists have differed, and still differ, widely with regard to the relative value as tests of the age of strata, to be assigned to different *classes* of fossils. In certain cases—some of which will be more fully referred to subsequently—a different age would be assigned to a group of beds on the strength of its vegetable remains to that which would be deduced from a study of the animal fossils of the same or of associated beds. Or, the marine Invertebrate fossils in some cases may point to one age for the beds, while the remains of Vertebrates indicate another. Such cases must be dealt with on the following general principle :—

Deposits containing numerous land-plants or the bones of terrestrial Vertebrates are mostly estuarine, lacustrine, or fluviatile in origin, though in some cases they have been formed on land. On the other hand, deposits containing marine Invertebrates have been laid down in the sea itself, for the most part at moderate depths. There is, however, absolutely no reason for thinking that the succession of life as regards the land-plants and land-animals of any given region has been in any way parallel with the evolution of the marine animals of the seas of the same region. The evolution of the terrestrial organisms may have been much more rapid or much slower than that of the marine forms. Hence, it is quite possible that the land-plants and land-animals which are regarded as characteristic of a particular geological period, may be found coexisting with marine animals which are considered to characterise a different geological period. If, however, we take the stratified formations as a whole, we find that it is in the main by means of their marine faunæ that their relative age has been determined, the reason of this being the obvious one that the great majority of stratified deposits have been laid down in the sea, and the record of the succession of terrestrial organisms in time is a very incomplete one. The general chronological standard, as based upon palæontological evidence, is, therefore, founded mainly on the results afforded by the marine Invertebrates. In those cases, therefore, in which the marine deposits of a given series of beds would indicate through their Invertebrate fossils

a particular stage in chronological succession, while the fresh-water or terrestrial deposits of the same series through their vegetable remains would indicate another, it is to the former that we should give the precedence as determining the age of the entire series. Such cases are sometimes spoken of as instances of "homotaxis," but this is not strictly so. In the particular cases here in question, two sets of beds, which may have been formed contemporaneously, are found to contain fossils of apparently different geological ages, in consequence of the fact that the beds have been formed under different conditions, the one containing the remains of land-plants, and the other the remains of marine Invertebrates. The apparent difference of age is due to the fact that the evolution of the land-flora in the particular region where the beds are found has not been parallel with that of the marine fauna of the same region. On the other hand, "homotaxial" deposits, properly so called, are deposits which have been formed during the same geological period, and have been laid down under similar conditions, thus coming to contain similar classes of fossils, but which have been formed in regions very far apart. The similarity, or identity, of the fossils in the two sets of beds proves them to belong to the same general period; but their geographical remoteness is a proof that they were formed at different stages of this period, and that they were not precisely identical. Together with the similarity of certain types of life in "homotaxial" beds, there is found a dissimilarity as regards other types, this being a consequence of the fact that the two sets of beds have been formed in widely distant areas, and therefore in distinct zoological provinces. In other words, the dissimilarity in the fossils in "homotaxial" beds, in the strict sense of the term, is dependent on the *distance in space* of the beds, and is not due to difference of *origin*.

An excellent concrete example of the above general principle is afforded by the so-called "Dakota Beds" of North America. These are largely developed in the basin of the Upper Missouri, are mainly of brackish-water or fresh-water origin, and contain a series of plant-remains the general aspect of which is clearly Tertiary. If judged, therefore, by purely palæobotanical evidence, the "Dakota Beds" would be assigned to the Eocene system. The "Dakota Beds" are, however, overlain by some thousands of feet of stratigraphically younger deposits charged with marine fossils of Cretaceous type. Judged, therefore, by a palæozoological standard, the "Dakota Beds" must be assigned to the Cretaceous period. The explanation of this discrepancy in the age of the beds as deduced from the plants and animals respectively is apparently twofold. On the one hand, the "Dakota Beds" are mainly of fresh-water origin, whereas the strata by which they are surmounted were laid down in the sea. On the other hand, we must suppose that the Tertiary flora had been introduced into the American area at a time when the seas of the same area were still tenanted by the characteristic animals of the Cretaceous period, and that the latter were not replaced by the animals distinctive of the Tertiary period until long after the land-vegeta-

tion had assumed the Kainozoic facies. That the "Dakota Beds" are truly of Cretaceous age is further shown by the fact that part of the series is marine in origin, and that in it are met with the remains of such characteristic Cretaceous types of Invertebrates as Ammonites and Belemnites.

A somewhat more complicated case is that of the so-called "Laramie Beds," or "Lignitic Series," of North America. These constitute a series of beds, of some thousands of feet in thickness, which repose upon strata with marine fossils of unquestionable Cretaceous type, and are unconformably surmounted by strata containing equally unquestionable marine Tertiary (Eocene) fossils. The "Laramie Beds" are admittedly of purely inland origin, and were probably laid down in a vast brackish-water lake. The Invertebrate fossils which they contain consist almost wholly of brackish-water, fresh-water, and terrestrial Molluscs, and the characters of these are such that they do not afford a decisive test of the age of the series. The remaining fossils are mostly those of land-plants or of terrestrial Vertebrates, and the evidence as to age yielded by these respectively is discrepant, the vegetable remains being of distinctly Tertiary type, while the Vertebrates belong to the characteristic Mesozoic group of the Dinosaurian Reptiles. When we consider, however, that the evidence afforded by the "Dakota Beds" and the strata overlying these renders it certain that the Tertiary vegetation had been introduced into America at a time when the marine Invertebrates of the Cretaceous period still existed in full force, we cannot attach much value to the plant-remains of the "Laramie Group" as indicating a reference of these strata to the Tertiary period. Adding to this consideration the presence of such characteristic Cretaceous Vertebrates as the Dinosaurs, and the further fact that the Laramie beds are surmounted *unconformably* by beds of unequivocal Eocene age, it seems difficult to resist the conclusion that these disputed strata are either truly of Cretaceous age, or that they form a transitional group between the Cretaceous and the Tertiary systems.

A good example in the European area of the contradictory evidence sometimes yielded by different classes of fossils as tests of age is afforded by the "Pikermi Beds" of Attica. These beds contain an abundance of the remains of terrestrial Mammals, which have generally been regarded as of a distinctively Miocene type; and on the strength of this the "Pikermi Beds" have been referred to the Upper Miocene period. The mammaliferous clays of Pikermi repose, however, upon strata containing marine Molluscs of unquestionable Pliocene type. The explanation of this appears to be, that the terrestrial Mammals of the Miocene period had persisted unchanged in the south-east of Europe, while the Miocene Mollusca of the Mediterranean had been replaced by the later Pliocene forms. Since it is by the marine Invertebrates that the age of strata can be most uniformly and most reliably judged, we are thus bound to refer the "Pikermi Beds" to the Pliocene period.

Contemporaneity and Homotaxis.

The discovery of the use of fossils as tests of the age of the sedimentary rocks, and the recognition of the fact that by their means a chronological succession of the stratified deposits of any particular region could be established, constituted great advances in geological

science, as also in Palæontology itself, but they led at first to erroneous generalisations. When it had been clearly established that particular groups of strata in Europe were characterised by particular assemblages of animals and plants, it was, not unnaturally, concluded that similar or identical assemblages of organisms would be found to characterise corresponding groups of strata all over the world. This led to the idea that the successive faunæ and floræ observable in the area first examined had been *universally distributed over the whole globe;* from which followed the old catastrophistic view that the close of each geological period had been signalised by a more or less complete extinction of the animals and plants then in existence, and that a new fauna and flora had been introduced at the commencement of each succeeding period.

It is, however, now universally admitted that in nature the chronological succession of the rocks, as determined by fossil remains, is local and not universal—in the sense that the precise order of phenomena must necessarily have differed in different regions. That this must be so is proved by the existence at the present day of "zoological provinces"; by the fact that dry land and sea must always have existed since the beginning of Palæozoic time at any rate, and that sedimentation can, therefore, never have been universal; and by the certainty that the sedimentary deposits now in process of formation, and therefore necessarily coeval, contain the remains of dissimilar groups of animals and plants.

In view of these considerations, it is necessary to consider what precise significance is to be attached to the term "contemporaneous" as applied to different groups of strata. When groups of beds in different parts of the earth's surface, however widely separated from one another, contain the same fossils, or rather an assemblage of fossils in which many identical or closely allied species occur, they are generally said to be "contemporaneous"—that is to say, they are ordinarily supposed to belong to the same geological period, and to have been formed at the same time in the history of the earth. They would therefore be ordinarily regarded as "geological equivalents," and would be classed as Silurian, Devonian, Carboniferous, and so on. The use of the term "contemporaneous" in the above comprehensive sense cannot, however, be accepted without serious qualification. Within the limits of a single geographical area of moderate size, beds containing identical, or nearly identical, fossils, may doubtless be safely regarded as strictly "contemporaneous," since there is no reason why such should not have been deposited within one ocean, and during a single geological period. When, on the other hand, we find precisely identical or even representative species of fossils in beds which are very widely removed from one another geographically, there is a presumption that such beds are *not* exactly

contemporaneous, but that they succeeded each other in point of time, though not necessarily by any very long interval geologically speaking. The general ground for this presumption is the readily intelligible one that such beds, if sufficiently far apart, must have been deposited in different oceans, but that we cannot suppose that any given species could have been developed to begin with in more than one ocean. When, therefore, we find identical species in strata in two widely remote areas, we are forced to conclude that these species must have appeared sooner in one area than in the other, and that the one set of strata must be later than the other, if by no more than the time required for the migration of these species from their original area to the other.

Most of the facts bearing upon this question may be elicited by a consideration of such a well-known and widely extended group of deposits as the marine division of the Carboniferous system, of which the chief member is the Carboniferous Limestone. This group of deposits is more or less extensively developed in regions as remote from one another as Europe, Central Asia, China, Japan, Australia, South America, and North America; and it is characterised by an assemblage of distinctive fossils, among which certain species of Brachiopods are specially noteworthy. Not only are the Carboniferous Brachiopods in these widely distant areas referable to the same *genera* (*Producta*, *Athyris*, *Streptorhynchus*, &c.), but identical *species* are in some cases found to range over the greater part of the vast area occupied by these deposits.[1] Now, if we believe that the Lower Carboniferous rocks in all these widely distant regions were "contemporaneous," in the sense that they were deposited at precisely the same time, we should be compelled to admit the existence during Carboniferous time of an ocean embracing all these points, and, in spite of its enormous extent, so uniform in temperature, depth, and the other conditions of marine life, that organisms either the same, or very nearly the same, inhabited it from end to end. We can, however, point to no such uniformity of conditions and consequent uniformity of life over any such vast area at the present day; and we have, therefore, no right to assume that this is the true explanation of the facts. Moreover, all that we know of the geographical distribution of recent organisms would prove that these identical species cannot have been produced simultaneously in all the areas where their remains are now found, but that they must have been dispersed

[1] Among the commoner and more characteristic types of Brachiopods found in the Lower Carboniferous rocks of Europe, *Producta semireticulata*, *P. longispina*, *P. aculeata*, *P. costata*, and *Streptorhynchus crenistria* occur, along with other European forms, in the Carboniferous rocks of China (Kayser). All these species, with the exception of *P. costata*, have been identified in the Carboniferous deposits of Australia and India; and all of them occur, with various other European types, in the Lower Carboniferous rocks of North America.

from one or other of these areas, or from some point still unknown; and this dispersal must necessarily have consumed a long period of time. Any other view would lead us almost inevitably to the now abandoned theory that each period in geological history was characterised by a special group of organisms spreading over the whole globe, and that there took place at the close of each period a general destruction of all existing forms of life, and a fresh creation of the new forms characteristic of the next period.

In our inability, then, to accept this view, we must seek for some other explanation of the observed facts. The most probable view, and the one which is supported most strongly both by what we see at the present day and by what we learn from numerous examples in past time, is this: The Carboniferous Limestone—to take this member of the Lower Carboniferous deposits in particular — was not deposited all over the world in one given period, by one sea, or at exactly the same time; so that it cannot be said to be strictly "contemporaneous" wherever it is found. This would imply a uniformity of conditions over vast distances, such as exists nowhere at the present day, and such as we have no right to assume ever existed. On the contrary, the deposition of the Carboniferous Limestone must have first taken place in one comparatively limited area—say in Europe—where fitting conditions were present both for the animals which characterise it, and for the formation of beds of its peculiar mineral and physical characters. How wide this area may have been, signifies very little. It may have been as large as the area now covered by the Pacific, or larger, and yet it could not include all those localities in which strata of Lower Carboniferous age with identical or representative fossils are already known to exist. Under any circumstances, some dispersion of the species of the original Carboniferous area must have been going on by the ordinary processes of migration from the commencement of the Carboniferous period, but this dispersion must have been greatly accelerated towards the close of the period of the deposition of the Carboniferous Limestone. At this time the conditions present in the original area must be supposed to have become unsuitable for the further existence in that area of the assemblage of animals which had been its inhabitants, or, at any rate, for a great many of them. The change from suitable to unsuitable conditions must, it is hardly necessary to say, have been an extremely slow and gradual one, and would doubtless be connected with the progressive shallowing of the sea, the diversion of old currents of heated water, or the incoming of new currents of cold water, or other physical changes tending to alter the climatic conditions of the area. What, then, would be the effect of such a change of conditions as we have supposed, upon the animals inhabiting the area? —Some of them would, doubtless, be sufficiently hardy and accom-

modating to bear up under the new state of things; and these would persist into the ensuing period, without any perceptible change, it might be, or more probably in the form of varieties or species allied to the old ones. In this case, therefore, we should get a certain number of species which would pass from the Carboniferous Limestone up into the Yoredale series, the Millstone Grit, or the Coal-measures; or, if we did not find any species exactly the same in all these groups, we should still find in the later groups some forms which would be varieties of those of the older, or which would be allied or representative species.

There would, in the second place, be a certain number of species which would be utterly unable to withstand the altered conditions of the area; and these would gradually die out and become wholly extinct. We should thus get a certain number of fossils which would be either exclusively confined to the Carboniferous Limestone in general, or which, perhaps, might not be found out of the Carboniferous Limestone of a single region, or even of a single particular locality.

Lastly, some species would yield so far to the altered conditions of the area that they would "migrate," and seek elsewhere a more congenial home. This term is apt to convey false impressions; and it will be well here to consider what is meant by the "migration" of species or groups of animals. It is quite obvious that only animals like birds, mammals, insects, &c., which enjoy when grown up the power of active locomotion, can actually "migrate" in person, supposing they find themselves placed under unfavourable conditions. There are many animals, however, such as most Molluscs, Corals, Polyzoans, &c., which have, when adult, either no power of changing their place, or at best a very limited one. Still in these cases even, though the *individual* has no means of removing his quarters to some more favoured spot, there may be a "migration" of the *species* from an unsuitable to a suitable locality. This is effected through the medium of the young, which have the power of choosing where they will settle, and are endowed with vigorous powers of locomotion. If, for example, a bed of oysters should become placed under conditions unsuitable for the development of these Molluscs, it is clear that the old oysters cannot change their location. The young oysters, however, swim about freely; and these will move away from the original bed till they find a place which will suit them. By a repetition of this process there may be in course of time a removal or "migration" of a species to almost any distance, irrespective of the fact that the adult is permanently rooted.

To return, then, to the case which we have been considering: When the conditions of life in the seas of the Carboniferous Limestone became unfavourable for the further existence of their fauna,

some species would migrate to a more congenial area. In this way a greater or less number of the species characteristic of the Carboniferous Limestone would ultimately be transferred to some other area. Here they would mingle with the forms already inhabiting that area, perhaps more or less completely supplanting these, or perhaps merely succeeding in maintaining a more or less precarious existence. In either case, their remains would be preserved in the sedimentary deposits of the new area. When, ages afterwards, we come to examine the crust of the earth geologically, we should find these identical and characteristic species of fossils in the rocks of the two areas, and we should say—"these rocks are contemporaneous." It is clear, however, that we should be wrong in so saying. The rocks in question would belong to the same geological period, but they would belong to different stages of the same period, and they would not be strictly contemporaneous. For deposits of this nature, believed to hold this relation to each other, the term of "homotaxial" has been proposed, in place of the term "contemporaneous."

What has just been said about the Carboniferous rocks would apply with equal justice to all the great formations, and to many of the smaller rock-groups all over the world. The Ordovician and Silurian rocks of Europe, North America, South America, Australia, &c., contain very similar fossils, and are undoubtedly "homotaxial." Nothing, however, that we see at the present day can justify us in believing that these widely separated deposits are strictly "contemporaneous," in the sense that they were deposited at exactly the same period of time. We should have to believe, if this conclusion is to be justified, that in Ordovician and Silurian times the ocean spread over a much larger area of the earth's surface than it does now, and that its temperature and depth were unnaturally uniform; and there are, perhaps, some who would accept this view. What has been said about the Ordovician and Silurian rocks as a whole, applies with still greater force to certain of the minor subdivisions of the same, which contain many of the same specific forms in parts of the globe very widely removed from one another. It is the very identity of the fossils, however, which proves that the beds in question, from their geographical position, cannot have been deposited at exactly the same time, though they doubtless belong to the same period, and may even be said to be related to one another, so far as their identical fossils are concerned, by lineal descent. Similar remarks might be made about the Devonian, Permian, Triassic, Jurassic, Cretaceous, and other formations; but it is not necessary further to multiply examples.

If we consider the present state of things upon the globe, we shall be further convinced of the justice of these views, which were first prominently brought forward in Britain by Professor Huxley.

If we could suddenly remove the sea from the earth, we should find at various points of the earth's surface deposits of different kinds, now concealed from us by the ocean, or only partially known by dredgings or soundings. Thus we should find vast accumulations of calcareous matter, in the form of coral-rock and coral-reef, where now rolls the Pacific Ocean. In high northern and low southern latitudes we should find great deposits of sand and mud, with angular blocks of stone, the whole derived from the ice-clad regions of the poles. Over vast areas, again, in the deep Atlantic, we should find an impalpable chalky mud, or "ooze." All these different deposits are obviously and necessarily "contemporaneous," not only in the geological acceptation of the word, but in its most literal sense. In spite of this fact they would not contain the same fossils; and, indeed, they would be characterised by organic remains which would be wholly different in each case. The coral-reefs of the Pacific would be essentially characterised by the abundance of the remains of reef-building corals, though they would also present other tropical forms of life, especially Brachiopods and Echinoderms. The glacial mud of the Polar regions would contain the remains of Arctic Molluscs, along with such other animals as delight in severe cold. Lastly, the ooze of the deep Atlantic would contain innumerable *Foraminifera*, along with siliceous Sponges and Crinoids. We learn, therefore, from this, that contemporaneous deposits not only do not necessarily contain the same fossils, but that, if widely separated geographically, they may be characterised by wholly dissimilar assemblages of organisms.

It may happen, again, as pointed out by Sir Charles Lyell, that deposits belonging to different geographical and zoological provinces may, as regards space, be nearly approximated, and, as regards time, may be actually contemporaneous, and yet may not contain any fossils in common, or only a very few. If, for example, any sudden upheaval were to lay bare what is now the floor of the Red Sea, together with that of the Mediterranean, we should find the two areas to contain deposits actually synchronous as regards the time of their deposition, and very near to one another in point of distance, and yet containing, upon the whole, entirely distinct groups of organic remains. We learn, therefore, from this, that owing to the existence of geographical barriers, it is possible for contemporaneous deposits to be found in close contiguity, in a single region, and yet to contain very different fossils.

Again, it has been abundantly proved that even within the limits of a single ocean deposits are now in process of formation which, though strictly contemporaneous in point of time, nevertheless differ from one another altogether both in mineral characters and in their included organic remains. Thus, the mechanical deposits formed

on the borders of an ocean, in the neighbourhood of land, differ wholly in mineral character from the peculiar "muds" formed in the profound depths of the same ocean; an equal difference existing as to the character of the animals buried in each. We thus learn that marine deposits may be strictly contemporaneous, and may be placed near to one another in point of distance, and yet may be wholly unlike both lithologically and zoologically. Lastly, synchronous deposits necessarily contain wholly different fossils, if one has been deposited by fresh water and the other has been laid down in the sea. The fresh-water deposits of one period are obviously contemporaneous with the marine formations of the same period, and they may not be far removed from one another in point of distance, but they must contain altogether different organic remains. The former will contain remains of the fresh-water and terrestrial animals of the period, and of these only; whilst the latter will principally, if not exclusively, be characterised by the remains of marine forms of life. In this way, there is reason to believe, may be explained the differences between the fossils of the Old Red Sandstone and of the Devonian rocks, strictly so called. Both are believed to have been deposited in the same geological period, and to be truly "contemporaneous"; but they do not contain the same fossils. This may be readily explained, however, if we suppose the former to represent the fresh-water deposits of the Devonian period, or to have been laid down in an inland sea, whilst the latter is the true marine formation of the same period.

In the strictest sense, then, of the term, deposits may be spoken of as "homotaxial" when they contain identical or closely allied fossils, but have nevertheless not been laid down at precisely the same time. If such deposits are widely separated from one another in space, then the possession of identical fossils is a direct argument in favour of a want of absolute contemporaneity—supposing that the deposits compared have been formed under similar conditions, in which case alone a complete comparison is possible. Thus, the Lower Carboniferous rocks of Britain, Russia, China, and North America are all marine in origin; and the fact that they contain identical species of Brachiopods is thus an argument in favour of the view that they were not formed at *precisely* the same time, since they are so widely apart that they cannot be regarded as having been simultaneously laid down within the limits of a single ocean. Nevertheless, the deposits in question were laid down in the same geological period, and are therefore "geological equivalents." The doctrine of "homotaxis," therefore, if rightly limited and defined, in no way diminishes the value of fossils as indicative of the age of the formations in which they occur. If we give the term "contemporaneous" a purely geological sense, and

endeavour to forget its literal signification as applying to events which have occurred at precisely the same moment of time, then it is just as good an epithet for the different deposits belonging to a given geological formation as is the term "homotaxial." All the deposits which possess Carboniferous fossils, at whatever point of the earth's surface they may be situated, belong to the Carboniferous period, and are therefore geologically contemporaneous. All that is really implied by the doctrine of "homotaxis," rightly regarded, is that we cannot say that any great formation in any one country is the precise equivalent of the same formation in any country very widely removed in point of distance, in the sense that its deposition began and ended at exactly the same times; and therefore we cannot parallel the subdivisions of such formations with anything approaching to absolute precision. Regarded as a whole, however, the Carboniferous formation of America is the geological equivalent of the Carboniferous formation of Europe, and both belong to what geologists understand as the "Carboniferous period." As the same is true of all the great formations, in all parts of the world, it is clear that the principal advantage of the use of such a term as "homotaxis" is simply that we thereby avoid the employment of a word which common usage would wrongly interpret; and it is quite certain that we cannot abolish the idea of *geological* "contemporaneity," as demonstrated by the presence of identical or representative species of fossils; nor can we refuse to admit that formations containing such fossils, however far removed from one another in point of distance, must have been laid down within the limits of the same great "period" in the history of our earth.

In the case of the Lower Carboniferous deposits above alluded to, not only are the fossils generally similar to one another in all the widely separated regions in which these strata have been recognised, but certain characteristic *species* seem to have an almost universal distribution. The enormous range of certain specific types remains a most noteworthy fact, whatever explanation may be given of it. As a general rule, however, deposits in different geographical areas, which occupy a corresponding position in the series of the stratified rocks, and are therefore geologically speaking "contemporaneous," contain but few or no actually identical *species*. The faunæ of such deposits, on the contrary, are usually composed of allied or representative forms, the same groups of animals being the ones prevalent in and characteristic of the deposits, but the *species* being different. Thus, there can be no doubt that the Devonian deposits of North America and Western Europe are geological equivalents, since they occupy in each region the interval between the highest Silurian and the lowest Carboniferous sediments. The fauna of the Devonian rocks of North America, also, presents a close general resemblance to that of the Devonian of Devonshire, Belgium, and Germany. In both cases there is a predominance of certain special groups of animals, amongst which the great Hydrozoal group of the Stromatoporoids may be particularly singled out. The Stromatoporoids of the American

Devonian represent those of the European Devonian, and certain peculiar generic types (such as *Idiostroma*) are common to both regions ; but there is, nevertheless, a marked difference as regards the forms most prevalent in each. Thus, the European Devonian is specially characterised by the prevalence of species of *Actinostroma* and *Stromatopora*, while the most characteristic types of the American Devonian belong to the genus *Clathrodictyon*, a genus which in Europe attains its maximum in the Silurian period. Again, only few *species* of Stromatoporoids are common to the two regions in question. Precisely similar facts could be brought forward with regard to the Corals, Brachiopods, &c., of the Devonian formation in these areas ; and the general law which these facts illustrate would seem to be one of very wide application.

In other cases, while the general fauna of two geologically equivalent deposits in widely remote areas is broadly similar, special organic types may occur in one or other area which indicate a later or an earlier age than that pointed to by the general assemblage of fossils. A marked example of this is found in the occurrence of such characteristic Secondary types of Cephalopods as *Ammonites* and *Ceratites* in certain strata in North-western India, the general fossils of which are of unequivocal Carboniferous type (Waagen). In this case, special organic types which are in general characteristic of a later age, are associated with a general fauna distinctive of an earlier period. An instance of the opposite of this —*i.e.*, of the occurrence of a special organic form of an earlier period in association with a general fauna of a later type—is found in the occurrence of Ammonites in California in strata containing abundant fossils characteristic of the Eocene Tertiary.

Geological Continuity.

We are now in a position very briefly to discuss the question of what may be called "geological continuity." It has already been stated that the entire series of Fossiliferous or Sedimentary rocks may be naturally divided into a certain number of definite rock-groups or "formations," each of which is characterised by the possession of a peculiar and characteristic assemblage of fossils, constituting, or rather representing, the "life" of the "period" in which the formation was deposited. The older geologists held, what probably every one would be tempted to think at first, that the close of each formation was characterised by a general destruction of the forms of life of the period, and that the commencement of each new formation was accompanied by the creation of a number of new animals and plants, destined to figure as the characteristic fossils of the same. This theory, however, not only invokes forces and processes which it can in no way account for, but overlooks the fact that most of the great formations are separated by lapses of time, unrepresented perhaps by any deposition of rock, or represented only in some particular area, and yet, perhaps, as great as, or greater than, the whole time occupied in the production of the formation itself.

Upon any theory of evolution, however, it must be held that

there was no such sudden destruction of life at the close of each great geological epoch, and no such creation of fresh forms at the commencement of the next period. On the contrary, it is certain that there is a geological "continuity," such as we see in other departments of nature, and that the lines which we draw between the great formations merely mark periods of time in which no rocks were laid down, or the rocks deposited in which are at present unknown to us.

What are we to believe occurred at the close of any great geological period—say, the Cretaceous period? If we reject the view that the close of the period was marked by a sudden and universal extinction and destruction of the characteristic Cretaceous forms of life, there is only one other view which we can take. Confining our attention solely to those seas of the period of which alone we know enough for safe reasoning, we know that the close of the Cretaceous period in Europe was accompanied, or rather caused, by an upheaval of the Cretaceous area, and an obliteration of the Cretaceous sea. This upheaval was, of course, effected with extreme slowness, or, at any rate, not suddenly, and it must have completely changed the life-conditions or "environment" of the animals which swarmed in the Cretaceous seas. Some of these would doubtless be unable to accommodate themselves to their altered surroundings, and would simply die out. Others, we may presume, would migrate to some more favourable area, and some of these might accomplish their migration without undergoing any change. Most of the forms which migrated, in the process of migration, and by reason of coming into contact with strange neighbours and untried conditions, would, however, probably undergo more or less modification. Ultimately, therefore, many characteristic Cretaceous forms might be transferred to some sea far distant from their original home. Not only so, but some of the transferred species might have suffered so much modification that they would no longer be regarded as specifically identical with the original Cretaceous forms, but would be looked upon simply as allied or "representative" species, though really the lineal descendants of the animals of the Chalk.

It is perfectly clear that the process of rock-deposition which was going on in Europe towards the close of the Cretaceous period was not, and could not be, abolished by the elevation of the European area, and the obliteration of the Cretaceous sea, but was simply *transferred* to some other area. In this particular case, we do not happen to know where the new area of deposition may have been. It is quite certain, however, that in whatever area the Cretaceous animals took refuge, there rocks must have been deposited in course of time, as they are in all seas, though it does not in the least follow that the rocks of this new era should have the smallest likeness in

mineral composition to the Cretaceous sediments. If we should at any time discover these rocks, it may pretty safely be predicted what we should find in them in the way of fossils. We should find, namely, some Cretaceous species, probably unchanged; with these there would be forms allied to the Cretaceous species, but differing from them to a greater or less extent; in addition, there would be a certain proportion of forms of life wholly unknown in the Cretaceous rocks; and lastly, there would be a conspicuous absence of certain characteristic species of the Chalk period. In other words, such deposits as we have been speaking of would contain an assemblage of fossils more or less intermediate in character between those of the true Cretaceous period and those of the lowest Tertiary beds (Eocene), which rest upon the Chalk; or they would present an intermixture of Cretaceous with Eocene types. In point of fact, we have fragments of such intermediate deposits (in the Maestricht beds of Holland, the Pisolitic Limestone of France, the Faxoe Limestone of Denmark, and the Thanet Sands of Britain), and we find in them traces of such an intermixture. Moreover, when we come to examine the boundary-line between the Cretaceous and Tertiary in other regions, we do actually meet with strata which have been deposited during the period marking in Europe the interval between the White Chalk and the lowest Tertiary deposits, and which contain, therefore, an intermixture of Cretaceous and Eocene types of life. The most celebrated of these transitional formations, so far as known, is the "Laramie Group" of North America, the precise position of which in relation to the strata above and below has been a matter of much controversy.

We may pause here to consider how it is that we may never hope to find a complete series of deposits linking on one great formation to another, as, for example, the Chalk to the Eocene rocks. In the first place, only a limited portion of the earth has as yet been properly examined, and we have therefore no right to expect that we have as yet hit upon the area, or areas, to which the process of rock-forming was transferred at the close of the Cretaceous period proper in Europe. We have, however, the full right to expect that we shall ultimately find formations which will have to be intercalated in point of time between the White Chalk and the Eocene; and, as before said, examples of such are already known to us. In the second place, we have every reason to suppose that many of these intermediate deposits have been destroyed at some period subsequent to their formation by what is technically called "denudation," or, in other words, by the action of rain, rivers, ice, and the sea. In the third place, many of the missing deposits may have been concealed since their formation by the deposition upon them of other newer rocks; or they may be situated in areas which are at

present covered by the ocean. Lastly, we must not forget that there may have been times in which great changes in life were actively progressing in areas in which there might be little or no contemporaneous deposition of rock, so that the extreme terms of a series might be preserved to us whilst all the intermediate links might have escaped record.

From these and similar causes, it is certain that we shall rarely be able to point to a complete series of deposits linking one great geological period, such as the Cretaceous, to another, such as the Eocene. Still, we may well have a strong conviction that such deposits must exist, or must have existed, as memorials of, at any rate, part of the time which elapsed between the close of the one formation and the commencement of the next. Upon any theory of "evolution," at any rate, it is certain that there can be no total break in the great series of the stratified deposits, but that there must have been a complete continuity of life, and a more or less complete continuity of deposition, from the Cambrian period to the present day. There was, and could have been no such continuity in any one given area; but the chain could never have been snapped at one point and taken up at a wholly different one. It remains certain, however, that we can never dispense with the division of the stratified series into definite rock-groups and life-periods. We can never hope to discover all the lost links of the geological chain, and the great geological systems will always be separated from one another by more or less evident physical or palæontological breaks, or by both combined. The utmost we can at present do is to arrive at the conviction that the lines of demarcation between the great formations only mark gaps in our knowledge, and that there can in nature be no *hiatus* in the long series of fossiliferous deposits.

Life-Zones.

While each geological rock-system is characterised by a general assemblage of distinctive types of animals and plants, the minor subdivisions of each system are likewise distinguished by the prevalence of particular forms of life. There are, no doubt, cases in which an extensive series of successive strata may appear to be characterised throughout by essentially the same organic types, there being apparently no restriction of special fossils to special horizons in the series. In so far as such cases have any real existence, they may be explained as instances in which a great series of sediments has been accumulated with such rapidity that there has been no time for marked biological changes, resulting in the dying out of old species and the introduction of new forms. In many cases, however, the apparent diffusion of the same kinds of fossils from the base to the summit of

a series of beds perhaps two or three thousand feet in thickness, is due simply to the fact that the organic remains met with in the formation have not been sufficiently investigated, and that the exact horizon at which each occurs in the series has not been accurately determined. The determination of the horizons of particular life-forms is a work of time, and demands both great stratigraphical knowledge and also a wide and accurate acquaintance with the characters of the fossils themselves—two requirements rarely fulfilled in the same individual.

In a considerable number of cases, however, it has now been shown that the fossils of a given formation may be divided into two principal groups. In the one group is comprised a series of common forms of life which may be regarded as characterising the formation *as a whole.* In the other group are included certain special fossils confined to particular parts of the formation, and characteristic of certain definite *horizons* or *zones* within the limits of the formation. All the great formations are to some extent capable of being broken up into minor rock-groups, characterised by special life-forms. Some of the differences in the kinds of fossils found in different parts of the same formation must, of course, be simply set down to the fact that different kinds of sediment imply changed conditions in the sea, and hence changes in the marine fauna. If, for example, part of a formation consisted of limestone and part of sandstone, we should expect, beforehand, to find that each of these rock-groups would have some fossils not found in the other, since the two would have been formed under different conditions. Apart, however, from differences arising from causes of this nature, we meet with cases in which a formation, even if essentially homogeneous in its mineral nature, can be divided into *zones*, each of which is characterised by the possession of special groups of fossils. Organisms belonging to any class of animals may serve in this way as test-forms (" Leit-fossilien ") for special horizons in a series of stratified formations, but there are particular groups of fossils which have been found to be pre-eminently available for this purpose. Among the older rocks of the earth's crust, the forms which have proved specially valuable for the determination of particular " zones " are the Graptolites, the Trilobites, and the Brachiopods, while the Cephalopods have been found to afford the most satisfactory tests in the case of the Secondary rocks. A well-known instance of this subdivision of a system of strata by means of special types of fossils is that afforded by the Ordovician and Silurian rocks of Europe, in which palæontologists, following Professor Lapworth, have recognised numerous well-marked " life-zones," characterised for the most part by the possession of particular types of Graptolites, though in some cases the distinctive fossils belong to other groups. Another well-

known example of the same phenomenon is afforded by the Jurassic deposits. These have been shown to contain a number of well-marked zones, each of which is characterised by the possession of some special fossils, and particularly by some special Ammonite. These zones are extremely constant, in any particular region, and they enable the observer to effect a division of the formation into special horizons, which have no stratigraphical existence, and are not separated by any physical break, but are of the utmost palæontological importance, and can be rendered readily available in working out the stratigraphy of any given area.

Certain life-zones appear to have nothing more than a local development and importance, but in other cases they have proved to be astonishingly constant even over very large areas. Perhaps the most remarkable known instance of the extension of particular life-forms over a vast area is that afforded by the Arenig rocks (a subdivision of the Ordovician system), which have been recognised as occurring in Europe, in Canada, and in Australia, and contain in all these widely remote areas the same peculiar types of Graptolites.

The principal difficulty that we have to confront in dealing with these "zones," is to produce any plausible explanation accounting for the destruction of the special life-forms of the one zone and the appearance of those of the next zone. For the most part, these zones are of very limited vertical extent, and they succeed each other in such a manner as totally to preclude the idea that the dying out of the old forms can have been in any way caused by a physical disturbance of the area. Perhaps the most probable view to adopt in the meanwhile is, that the formations in which distinct and limited life-zones can be recognised were deposited with extreme slowness; whereas those which show an essentially compact and homogeneous fauna from base to summit were deposited with comparative rapidity. Upon this view, a formation like the Lias is one formed by a process of very slow and intermittent sedimentation, the life-zones being separated by intervals, during which sedimentation must have been at a stand-still, but which were long enough to allow of more or less considerable biological changes, some forms dying out, or becoming modified, while other new ones came in. Upon this view, further, a formation like the Lias, though of comparatively small vertical extent, may represent as long a period of time as the whole of such a great formation as the Lower Carboniferous, which appears to have been formed under conditions of comparatively rapid sedimentation.

"Colonies."

It only remains in this connection to consider very briefly the doctrine of "colonies," laid down by M. Barrande, the eminent

Bohemian palæontologist. It has been laid down as a law that when once a species disappears it never again makes its appearance in the geological record. This is almost certainly true, so long as we remember that it can only apply to cases in which a species has entirely and totally disappeared from the earth, and that it is often very difficult, or altogether impossible, to obtain evidence as to the exact time at which a given species has thus become actually extinct. There are plenty of cases in which a species seemingly disappears in a particular set of rocks, to reappear in some higher and later set of rocks in the same region, whilst its remains are wanting in all the intermediate deposits of the area. It also often occurs that a species, having disappeared in one region, is found in deposits of a later age in another area. The above-mentioned law, therefore, can obviously only hold good of cases in which a species has definitely and finally become extinct; and this implies an amount of knowledge on our part which we seldom or never possess. M. Barrande, however, has endeavoured to prove that there are other cases in which groups of species peculiar to one set of beds may appear in a temporary and sporadic manner in a much earlier set of beds, the two deposits thus characterised being separated by beds containing fossils peculiar to the earlier and older series. Thus, the Ordovician and Silurian rocks of Bohemia are characterised by very distinct assemblages of fossils. According to M. Barrande, however, the Ordovician rocks contain in places a group of fossils characteristic of the Silurian series. The beds containing this "colony" of Silurian forms are succeeded by strata filled with Ordovician fossils; and it is only after several alternations of this kind that the Silurian fauna comes in definitely and generally. These temporary appearances of a later fauna in the midst of an older fauna are termed by M. Barrande "colonies," and he explains their occurrence as follows: If we suppose the seas of the Bohemian area to have been peopled with Ordovician animals at a time when other portions of Europe were covered by a sea containing Silurian animals, and suppose the former area to have been shut off from the latter by a land-barrier, we can readily understand how "colonies" might be produced. If, from any cause, a channel of communication were opened between the Bohemian area and the general area of Northern Europe, an immigration of species would take place from the latter into the former area. The Silurian species of the latter area would thus be imported, in greater or less numbers, into the midst of the general Ordovician fauna of Bohemia, and would be preserved in the Ordovician rocks. If, however, the channel of communication were speedily closed, so that the newcomers could not be constantly reinforced by fresh immigrants, the "colonial" species would die out, and the general Ordovician fauna would again reign supreme. A reopening of the channel of com-

munication would allow of a fresh immigration and the formation of a fresh "colony," and the process might be indefinitely repeated. Finally, however, we must suppose that the Bohemian area was permanently thrown open to immigration from the general European area, when the Silurian fauna of the latter would succeed in permanently and completely displacing the old Ordovician fauna of the former region. The phenomenon, therefore, of "colonies" may be defined as "the coexistence of two general faunas, which, considered in their entirety, are nevertheless distinct;" and it is to be regarded as merely a case of migration under certain peculiar and exceptional circumstances.

Not only have the phenomena described by M. Barrande in connection with his "colonies" never been recognised with any certainty in any region outside Bohemia; but there are strong grounds for believing that the actual facts in this area will not bear the interpretation which has been placed upon them by this distinguished palæontologist. Thus, Mr J. E. Marr, after a careful examination of the facts on the spot, was led to the conclusion that the so-called "colonies" have no real existence, but are the result of disturbances of the strata, being due, in reality, to the repeated "faulting down" of a band of the Silurian rocks among the underlying Ordovician deposits. This explanation seems to account adequately for the observed phenomena, and relieves us of the necessity of accepting a theory which can with difficulty be reconciled with the ascertained laws of the distribution of animals in past time.

CHAPTER IV.

THE IMPERFECTION OF THE PALÆONTOLOGICAL RECORD.

As has been already pointed out, the series of the stratified formations is an imperfect one, and is likely ever to remain so. The causes of this "imperfection of the geological record," as it has been termed by Darwin, are various; but it is chiefly to be ascribed to our as yet incomplete knowledge of the geology of vast areas of the earth's surface, to denudation, and to the fact that many of the missing groups are buried beneath other deposits, whilst more than half of the superficies of the globe is hidden from us by the waters of the sea. The imperfection of the geological record necessarily implies an equal imperfection of the "palæontological record"; but, in truth, the record of life is far more imperfect than the mere physical series of deposits. As we are here chiefly concerned with the biological aspect of the question, we may advantageously consider some of the main causes of the numerous breaks and gaps in the palæontological record at some length.

I. Causes of the Absence of Certain Animals in Fossiliferous Deposits.—In the first place, even if the series of the stratified deposits had been preserved to us in its entirety, and we could point to the sedimentary accumulations belonging to every period of the earth's history, there would still be enormous deficiencies in the palæontological record, owing to the differences in the facility with which different animals may be preserved as fossils. This subject is sufficiently important to render it advisable to consider each of the primary groups of the animal kingdom separately from this point of view:—

a. Protozoa.—As regards the sub-kingdom of the *Protozoa*, the Gregarines are destitute of hard parts, and have therefore left no traces of their past existence. The great majority of the Infusorian Animalcules are similarly destitute of hard parts, and are also unrepresented as fossils; though a few forms (*e.g.*, *Peridinium*) possess

an integumentary covering which under favourable circumstances is capable of preservation, and remains of these are believed to occur in some of the later sediments. Of the Rhizopods, the *Monera* and the most of the *Amœbea* have no hard structures, and are unknown as fossils, but a few of the latter possess a "test" which might possibly be preserved in the fossil condition. On the other hand, skeletal structures of lime or flint are almost always developed in the great Rhizopodous orders of the *Foraminifera* and *Radiolaria;* and these groups, therefore, have left abundant traces of their existence in past time.

b. Porifera.—A few of the Sponges (*Myxospongiæ*) are completely destitute of hard parts, and have therefore no palæontological history. The greater number of the *Porifera*, however, possess a calcareous or siliceous skeleton, which is more or less capable of fossilisation, and the record of such types is therefore a long and comparatively full one.

c. Cœlenterata.—Amongst the Cœlenterate animals, the Fresh-water Polypes (*Hydra*), the Oceanic Hydrozoa, the Jelly-fishes (*Medusidæ*), the Sea-blubbers (*Lucernarida*), the Sea-anemones (*Actinidæ*), and the *Ctenophora* are destitute of hard parts which could be preserved as fossils. The Jelly-fishes and Sea-blubbers, however, supply us with an instance of how a completely soft-bodied creature may leave traces of its past existence; for impressions left by the stranded carcasses of these animals have been detected in certain fine-grained rocks (*e.g.*, the Lithographic Slates of Solenhofen). On the other hand, the coralligenous Zoophytes or "Corals" (comprising the *Madreporaria* and most of the *Alcyonaria*) possess hard parts capable of preservation, and there are therefore few classes of organisms which are more fully represented in past time than the true Corals. As regards the *Hydrozoa*, most of the Hydroid Zoophytes have a horny skeleton, and do not become readily fossilised, though the large extinct group of the *Graptolites* is generally regarded as allied to the recent Sertularians. In a few of the *Hydractinidæ*, and in the whole group of the Hydrocorallines, a calcareous skeleton is present, and various fossil forms of these are known. In the great extinct group of the *Stromatoporoids*, now usually referred to the *Hydrozoa*, the skeleton was also of a calcareous nature.

d. Echinodermata.—Since the integument of the Echinoderms is liable to undergo more or less extensive calcification, this great division of animals is represented more or less completely in past time by all its sections. In the group, however, of the Sea-cucumbers (*Holothuroidea*), the calcareous structures so characteristic of other Echinoderms are reduced to their minimum; and accordingly, the evidence of the past existence of these animals is of a very limited description.

e. Annulosa.—The lowest division of the *Annulosa* (viz., that of the *Scolecida*) comprises animals almost without exception destitute of hard parts, and mostly living parasitically in the interior of other animals. With the exception, therefore, of some excessively problematical fossils which have been supposed to indicate the past existence of Ribbon-worms (*Nemerteans*), the palæontological history of the *Scolecida* is a total blank. Most of the true Worms (*Anarthropoda*) possess few or no structures by which we could expect to get direct evidence of their past existence. The Polychætous Annelides have, however, left ample traces of their former presence either by their horny jaws or by means of their investing tubes. There are also numerous fossils of the nature of burrows or "tracks" upon the mud or sand of ancient sea-bottoms, which have been regarded, with more or less probability, as having been produced by Annelides.

In the case of the higher *Annulosa* (*Arthropoda*), another law steps in to regulate their comparative abundance as fossils. Most, in fact almost all, fossiliferous formations have been deposited in water; and of necessity, therefore, most fossils are the remains of animals whose habits are naturally aquatic. As most deposits, further, are not only aqueous, but are also marine, most fossils are those of sea-animals. It follows, therefore, that the remains of air-breathing animals, whether these be terrestrial or aerial, can only be preserved in an accidental manner, so to speak—except the animal inhabit water (as the Cetaceans do), or except in the rare instances in which old land-surfaces have been buried up by sediment, and thus partially kept for our inspection. In accordance with this law, the most important and abundant fossil Annulose animals are *Crustaceans;* since these not only have a resisting shell or "exoskeleton," but are also generally aquatic in their habits. The air-breathing classes of the *Myriopoda* (Centipedes and Millepedes), the *Arachnida* (Spiders and Scorpions), and the *Insecta* or true Insects, on the other hand, have been much less commonly and completely preserved, though many of them are perfectly capable of being fossilised. Almost all such remains, moreover, as we have of these three great classes, are the remains of isolated individuals, which may have been accidentally drowned; or else they occur in hollow trees, or in fragments of ancient soils, or in vegetable accumulations such as coal and peat. There is, however, a considerable number of aquatic insects (but almost exclusively in fresh water), and there are many insects the larvæ of which inhabit water, whether this be fresh or salt; so that instances of these occurring as fossils are not very infrequent.

f. Molluscoidea.—With regard to the Molluscoids, the great majority of the *Polyzoa* and all of the *Brachiopoda* possess skeletal structures of a horny or calcareous nature, which are capable of preservation in the fossil condition. Both these classes of animals, therefore, possess

a long and tolerably complete palæontological record. In the case of the *Polyzoa*, however, the group of the fresh-water forms is not at present known to have any fossil representatives.

g. Mollusca.—This sub-kingdom requires little notice, since the greater number of its members possess hard structures readily capable of preservation in the fossil condition. Hence, all the great existing groups of Molluscs are more or less extensively represented in past time. The oceanic Pteropods, however, perhaps owing to their pelagic habit of life, or possibly as the result of their having fragile and easily destructible shells, have left a more incomplete record of their past existence than is the case with the other classes of Molluscs. Amongst the *Gastropoda*, again, the Sea-slugs and their allies (*Nudibranchiata*) possess no shell, and are unknown to the palæontologist; whilst the shell of the Land-slugs is extremely minute, and has only rarely been recognised as fossil. Lastly, the air-breathing terrestrial Molluscs, from their habits, rarely occur as fossils; whilst those which inhabit rivers, ponds, and lakes are less largely represented than marine forms, owing to the prepon derance of salt-water deposits over those of fresh water.

h. Tunicata.—The Tunicates, so far as living forms are concerned, are almost always destitute of skeletal structures, or possess only microscopic spicules of carbonate of lime. Only the most limited traces of the past existence of these animals have as yet been certainly detected; but it is quite probable that further investigations will considerably extend our knowledge on this point.

i. Vertebrata.—The majority of Vertebrate animals possess a bony skeleton, so that their preservation in a fossil state—so far as this point is concerned—is attended with no difficulty. Some of the fishes, however (such as the Lancelet, the Hag-fishes, and the Lampreys), have no scales, and either possess no "endoskeleton" or have one which is wholly or almost wholly unossified. The only evidence, therefore, which could be obtained of the past existence of such fishes would be afforded by their teeth; but these are wanting in the Lancelet, and are small and horny in the Lampreys: so that we need not wonder that these fishes are unknown as fossils. The higher groups of the fishes, however, taking everything into consideration, may be said to be abundantly represented in a fossil condition by their scales, bones, teeth, and defensive spines.

The Amphibians are tolerably well represented by their bones and teeth, and, as regards one extinct order, by integumentary plates as well. They have also left many traces of their existence in the form of footprints. Most living Amphibians, however, frequent fresh waters, or spend a great part of their time upon the land; and hence their remains would not be likely to be preserved in marine deposits.

The abundance of Reptiles as fossils naturally varies much, according to the habits of the different orders. Of the living orders, the Chelonians (Tortoises and Turtles) are by no means rare; since many of them are habitual denizens of fresh water or of the sea, whilst all are provided with a well-developed skeleton. The existing *Squamata* (Lizards and Snakes) and the *Rhynchocephalia* live chiefly upon the land, and do not therefore abound as fossils; but some extinct types of the former (the Mosasauroids) were marine in their habits, and have consequently been pretty fully preserved. The *Crocodilia*, again, are so essentially aquatic in their habits, that their comparative frequency in aqueous deposits is no matter of wonder, especially if we recollect that many of the extinct members of this order frequented the sea itself. Of the extinct orders of Reptiles, the great *Ichthyosaurs* and the *Plesiosaurs* and their allies were marine in their habits, and their remains occur in what may fairly be called profusion. The Flying Reptiles, or *Pterodactyles*, would not seem to have any better chance of being preserved than Birds, if as good, yet their remains occur by no means very rarely in certain formations. The terrestrial *Dinosaurs* and *Anomodonts*, again, come very much under the laws which regulate the preservation of Mammals as fossils; and their remains are chiefly, but not exclusively, to be found in fluviatile or estuarine deposits.

As regards Birds, their powers of flight, as pointed out by Sir Charles Lyell, would save them from many destructive agencies, and the lightness of their bones would favour the long floating of the body in water, and thus increase the chances of its being devoured by predaceous animals. In accordance with these considerations, the most abundant remains of Birds belong to species which frequent the sea-shore, lakes, estuaries, or rivers, or which delight in marshy situations; though in certain regions the principal fossil representatives of the class *Aves* are large wingless forms, of terrestrial habit, and with their bones largely filled with marrow instead of air.

Lastly, as regards Mammals, the record is far from being a full one, and from obvious causes. The great majority of Mammals live on land, and therefore are not likely to be buried in aqueous, and especially in marine, accumulations. That this cause is the chief one which has operated against the frequent preservation of Mammalian remains is shown by the fact that when we exhume an old land-surface, the remains of Mammals may be found in tolerable plenty. The strictly aquatic Mammals—such as Whales, Dolphins, and the like—are, of course, much more likely to have been preserved as fossils than the strictly terrestrial forms; but their want of integumentary hard structures places them at a disadvantage in this respect as compared with fishes. In a general way, we may conclude that the preservation of the terrestrial Mammals as fossils is due to

the occurrence of individuals being killed whilst swimming a river or some other piece of water, or being mired in a bog, or to the bones of those that had died on land being washed into some stream, and thence into a lake or into the sea, by floods; but there are other cases for which a different explanation must be sought. The most abundant remains of Mammals have been found in deposits which have been laid down in lakes.

II. Unrepresented Time.—In the second place, we have seen that the *geological* record is very imperfect, and this of necessity causes vast gaps in our palæontological knowledge. In this connection we may briefly consider the evidence which we possess as to the immensity of the "unrepresented time" between some of the great formations, and no better example can be chosen than that of the Cretaceous and Eocene rocks, as developed in Europe. In considering such a case, the evidence may be divided into two heads, the one palæontological, the other purely physical, and each may be looked at separately.

The Chalk, as is well known, constitutes in Britain the topmost member of the Cretaceous formation, and is the highest deposit there known as appertaining to the great Secondary or Mesozoic series. It is directly overlaid in various places by strata of Eocene age, which form the base of the great Tertiary or Kainozoic series of rocks. The question, then, before us is this, What evidence have we as to the lapse of time represented in Britain merely by the dividing-line between the highest beds of the Chalk and the lowest beds of the Eocene?

Taking the palæontological evidence first, it is found that not a single specific type out of the vast number of known Cretaceous fossils has hitherto been recognised with certainty as occurring in the immediately overlying Eocene beds. These latter, on the contrary, are replete with organic remains wholly distinct from those of the Cretaceous beds. It may be said, therefore, that the very extensive assemblage of animals which lived in the later Cretaceous seas of Britain had entirely passed away and become a thing of the past, before a single grain of the Eocene rocks had been deposited. Now it is of course open to us to believe that the animals of the Chalk sea were suddenly extinguished by some natural agencies unknown to us, and that the animals of the Eocene sea had been in as sudden and as obscure a manner introduced *en masse* into the same waters. This theory, however, calls upon the stage forces of which we know nothing, and is contradicted by the whole tenor of the operations which we see going on around us at the present day. It is preferable, therefore, to believe that no such violent processes of destruction and repeopling took place, but that the marked break in the life of the two periods indicates an enor-

mous lapse of time. The Cretaceous animals, in consequence of the elevation of the British area at the close of the Cretaceous period, must have mostly migrated, some doubtless perishing, and others probably becoming modified in the process. When the British area became once more submerged beneath the sea, and became again a fitting home for marine life, an immigration into it would set in from neighbouring seas. By this time, however, the Cretaceous animals must have mostly died out, or must have become greatly changed in their characters; and the new immigrants would be forms characteristic of the Lower Eocene. How long the processes here described may have taken, it is utterly impossible to say, even approximately. Judging, however, from what we can observe at the present day, the palæontological break between the Chalk and the Eocene indicates a perfectly incalculable lapse of time; for all species change or die out slowly, marine species especially so; and we have here the disappearance of a large fauna almost in its entirety, and its replacement by another wholly distinct.

In the second place, to come to the physical evidence, the Eocene strata in Britain are seen to rest upon an eroded and denuded surface of Chalk, filling up "pipes" and winding hollows which descend far below the general surface of the latter. Not only so, but the base of the Eocene rocks is commonly composed of a bed of rolled and rounded flints, derived from the Chalk, affording incontestable proof that the Chalk had been greatly worn down and removed by denudation before the Eocene beds were deposited upon its surface. In short, the Eocene rocks repose "unconformably" upon the Chalk, and this, as is well known, indicates the following series of phenomena: Firstly, the Chalk was deposited in horizontal layers at the bottom of the Cretaceous sea. Secondly, at some wholly indefinite time after its deposition, after it had become more or less consolidated, the Chalk must have been raised by a gradual process of elevation above the level of the sea, during which it would inevitably suffer vast denudation. Thirdly, after another wholly indefinite period, the Chalk was again submerged beneath the sea, in which process it would be subjected to still further denudation, and an approximately level surface would be formed upon it. Fourthly, strata of Eocene age were deposited upon the denuded surface of the Chalk, filling up all the hollows and inequalities of its eroded surface (fig. 15).

In the unconformability, then, between the Chalk and the Eocene rocks, we have unequivocal evidence—irrespective of anything that we learn from Palæontology—that the break between the two formations was one of enormous length. In Britain the interval of time thus indicated is not represented by any deposits; and in

Europe generally there are but fragmentary traces of such. We may be quite sure, however, that during the time represented in Britain by the mere line of unconformability between the Chalk and the Eocene, there were somewhere deposited considerable accumulations of sediment.

It is not probable that we shall ever discover any very considerable portion of these, considering the large extent of the terrestrial surface which is covered by the ocean. In New Zealand, however,

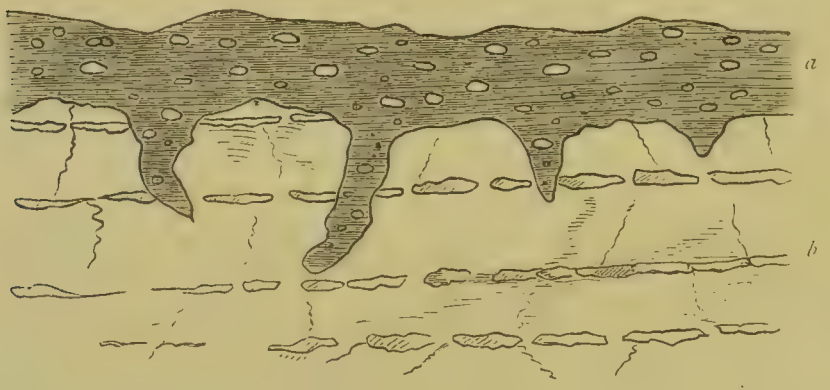


Fig. 15.—Section showing strata of Tertiary age (*a*), resting upon a worn and denuded surface of White Chalk (*b*), the stratification of which is marked by lines of flints.

and still more notably in North America, extensive deposits are already known, which were laid down subsequent to the formation of the White Chalk and prior to the deposition of the Eocene Tertiary, and which serve, therefore, to partially bridge over the great *hiatus* which separates these formations in Europe. These transitional formations are charged, as might have been anticipated, with the remains of animals which in part resemble Cretaceous types and in part are characteristic Eocene forms.

The break between the Cretaceous and lowest Tertiary deposits is one of the most extensive and universal of which we have at present any knowledge. Almost equally extensive and widespread is the break which separates the Palæozoic from the Mesozoic group of deposits. Throughout the whole stratified series, however, we meet at intervals with physical and palæontological breaks of greater or less magnitude. Sometimes a palæontological break occurs unaccompanied by marked physical disturbance or discordance of the strata; but usually a gap in the succession of life-forms is associated with clear physical evidence of elevation and subsequent denudation.

It may be pointed out that the unconformities above alluded to must be distinguished from the common cases in which strata of one age are *locally* superimposed in an unconformable manner upon

beds much older than themselves. These local unconformities are exceedingly common in regions which have undergone much disturbance, and they merely indicate that the region has been subjected to a local elevation, resulting in a temporary cessation of sedimentation in that particular area. In such cases, an examination of neighbouring areas, which remained submerged, and in which, therefore, sedimentation was uninterrupted, will show the missing deposits which were laid down during the period represented in the first area by a local unconformity. The instances above alluded to, though really only differing from the local unconformities just alluded to in nothing more than in being the result of a very widespread elevation, are distinguished by an important point. In the case of a mere local unconformity, we know what formation is wanting, and we can intercalate it from foreign areas, and can thus complete the series. In the general unconformities, such as that between the Palæozoic and Mesozoic groups of sediments, we are not at present acquainted with the deposits which were laid down during the interval represented by the physical discordance of the strata, and the series of rock-formations thus remains a broken one.

From the above facts, then, we learn that one of the chief causes of the imperfection of the palæontological record is to be found in the vast spaces of time which separate most of the great "systems," and which, so far as we yet know, are not represented by any formation of rock. In process of time we shall doubtless succeed in finding deposits to account for more or less of this "unrepresented time," but much will ever remain for which we cannot hope to find the representative sediments. It only remains to add that we have ample evidence within the limits of each formation, and wholly irrespective of any want of conformity, of such lengthened pauses in the work of deposition as to have allowed of great zoological changes in the interim, and to have thus caused irremediable blanks in the palæontological record. The work of rock-deposition is at best an intermittent process; the changes in a fauna, if slowly effected, are continuous. Thus there are scores of instances in which the fauna of a given bed, perhaps but a few inches in thickness, differs altogether from that of the beds immediately above and below, and is characterised by species peculiar to itself. In such cases we can only suppose, that though no physical break can be detected, the deposition of sediment was interrupted by pauses of incalculable length, during which no additional material was added to the sea-bottom, whilst time was allowed for the dying out of old species and the coming in of new. The incessant repetition of such intervals of unrepresented time throughout the whole stratified series is convincing proof that the palæontological record is, and

ever must be, a mere excerpt from the biological annals of the globe.

III. Thinning out of Beds.—Another cause by which the continuity of the palæontological record is affected is what is technically called the "thinning out" of beds. Owing to the mode in which sedimentary rocks are produced, it is certain that there must be for every bed a point whence the largest amount of sediment was derived, and in the neighbourhood of which the bed will therefore be thickest. Thus, if we take a series of beds, such as sandstones and conglomerates, which are the product of littoral action, and are deposited in shallow water near a coast-line, it will be found that these gradually decrease in thickness, or "thin out," as we pass away from the coast in the direction of deep water. On approaching deep water, however, we might find that, though the sandstones were rapidly dying out, the thickness of the entire series might still be preserved, owing to the commencement now of some deep-water deposit, such as limestone. The beds of limestone would at first be very thin, but in proceeding still in the direction of deeper water, we should find that they would gradually expand till they reached a point of maximum thickness, on the other side of which they would

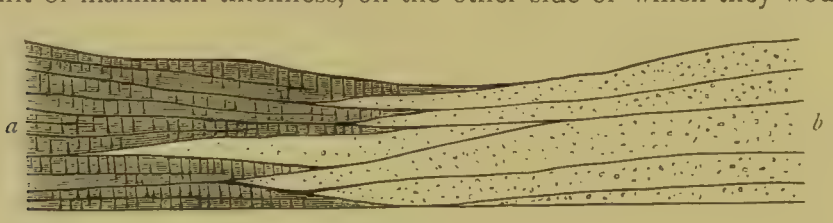


Fig. 16.—Diagram to show the "thinning out" of beds. *a*, Sandstones and Conglomerates; *b*, Limestones.

gradually thin out. Each individual bed, therefore, in any group of stratified rocks, may be regarded as an unequal mass, thickest in the centre, and gradually tapering off or "thinning out" in all directions towards the circumference (fig. 16).

In a general way this holds good, not only for any particular bed, but for any particular aggregation or group of beds which we may choose to take. In the case, namely, of every group of beds, there must have been a particular point whither sediment was most abundantly conveyed, or where the other conditions of accumulation were especially favourable. At this point, therefore, the beds are thickest, and from this they thin out in all directions. It need scarcely be pointed out, indeed, that some such state of things is unavoidable in the case of every bed or group of beds, since no sea is boundless, and the sedimentary deposits of every ocean must come to an end somewhere.

An excellent example of the phenomena above described may be

derived from the Lower Carboniferous rocks of Britain. Here we may start in South Wales and in Central England with the Carboniferous Limestone as a great calcareous mass over 1000 feet in thickness, and almost without a single intercalated layer of shale. Passing northwards, some of the beds of limestone begin to thin out, and their place is taken by strata of a different mineral nature, such as sandstone, grit, or shale. The result of this is, that by the time we have followed the Carboniferous Limestone into Yorkshire and Westmorland, in place of a single great mass of limestone, we have an equivalent mass of alternating strata of limestone, sandstone, grit, and shale, with one or two thin seams of coal—the limestones, however, still bearing a considerable proportion to the whole. Passing still further northwards, the limestones continue to thin out, till in Central Scotland, in place of the dense calcareous accumulations of Derbyshire, the Lower Carboniferous series consists of a great group of sandstones, grits, and shales, with thick and workable beds of coal, and with but few and comparatively insignificant beds of limestone.

The state of things indicated by these phenomena is as follows: The sea in which the Lower Carboniferous rocks of Britain were deposited must have gradually deepened from north to south. The land and coast-line whence the coarser mechanical sediments were derived, must have been placed somewhere to the north and north-west of what is now Great Britain, and the deepest part of the ocean must have been somewhere about Derbyshire. Here the conditions for lime-making were most favourable, and here consequently we find the greatest thickness of calcareous strata, and the smallest intermixture of mechanical deposits.

The palæontological results of this are readily deducible. The entire Lower Carboniferous series of Britain was probably deposited in a single ocean, apparently destitute of land-barriers; and consequently, taken as a whole, the fauna of this series may be regarded as one and indivisible. The conditions, nevertheless, which obtained in different parts of this area were very dissimilar; and, as a necessary result, certain groups of animals flourished in certain localities, and were absent or but scantily represented in others. In the deeper parts of the area we have an abundance of Corals, with Crinoids, and at times *Foraminifera*. In the shallower parts of the area there is, on the other hand, a predominance of forms which affect water of no great depth. Still there is no difference in point of time between the deposits of different parts of the area; and in order to obtain a true notion of the Lower Carboniferous fauna, we must add the fossils derived from one portion of the area to those derived from another.

In many cases, however, we are acquainted with but one class of

deposits belonging to a given period. We may have the comparatively deep-water deposits of the period only, or we may know nothing but its littoral accumulations. In either case it is clear that there is an imperfection of the palæontological record; for we cannot have even a moderately complete record of the marine animals alone of a particular period, unless we have access to a complete series of the deposits laid down in the seas of that period. A still more serious imperfection of the record arises where, as commonly happens, the marine deposits of a given period are alone known, and we are left without any knowledge of the lacustrine, fluviatile, and terrestrial deposits of the same period.

According to the views of Dr John Murray and the Abbé Renard, a very important deficiency exists in the series of sedimentary deposits known to us as forming the existing dry land, in so far as the series is without any representatives of the peculiar deposits which are now in process of formation in the deep sea. It has been shown by these investigators that between depths of six or seven hundred fathoms down to the greatest depths known, at distances of two hundred miles or more from land, there are now being formed certain remarkable deposits which may be spoken of as "deep-sea muds" and "abyssal clays." The deep-sea "muds" and "oozes" are exceedingly fine, mud-like deposits, which differ from true muds in not being made up of water-worn particles of clay or other mineral substances, and in being largely composed of the skeletons of minute animal or vegetable organisms. Some of these deep-sea muds are largely composed of the shells of *Foraminifera* ("Globigerina ooze"); others are essentially made up of the siliceous tests of *Polycystina* and allied organisms ("Radiolarian ooze"); others are built up principally of the shells of *Pteropoda* ("Pteropod ooze"); while others are the result of the accumulation of the flinty envelopes of Diatoms ("Diatom ooze"). The "abyssal clays," again, are red, purple, chocolate-coloured, or brown clays, composed of nearly impalpable particles, and almost destitute of calcareous matter, but sometimes containing particles of metallic iron or concretions of manganese. These abyssal clays, according to Dr Murray, are produced by the decomposition in sea-water of floating pumice and of ashes, ejected from volcanoes and ultimately falling into the sea; and there is evidence to show that they are the result of an excessively slow process of accumulation.

From a study of the deposits at present in process of formation in the deep sea, far from land, it has been concluded by Murray and Renard, as before said, that no similar or parallel deposits exist amongst the varied marine sediments which compose so large a portion of the present continents. On this view, the ordinary stratified rocks of marine origin have all been formed in comparatively shallow water,

or, at any rate, at a comparatively short distance from land. A conclusion so far-reaching as this requires, however, to be received with the utmost caution; the more so as it constitutes one of the most weighty arguments in favour of the equally far-reaching conclusion, that the present continental areas have been in the main regions of elevation, and the existing oceans in the main areas of depression, since the beginning of the Cambrian period, if not from a still earlier period. That a large number of the known sedimentary rocks have been formed from the wear and tear of pre-existing rocks, or have been the result of the accumulation of the skeletons of animals and plants, in comparatively shallow water and at moderate distances from a coast-line, may be taken as certain. With our present imperfect acquaintance, however, with the nature and origin of many of the older sediments of the earth's crust, it appears hazardous to conclude that *all* the sedimentary rocks have been laid down near land. In various parts of the stratified series we meet with deposits which may be paralleled with the Foraminiferal ooze, the Radiolarian ooze, the Diatom ooze, or even the Pteropod ooze of the present day, though it may be admitted that these deposits may sometimes have been formed in a comparatively shallow sea. Moreover, it cannot, with our present knowledge, be safely asserted that we have *no* ancient representatives even of the "abyssal clays" of the deep oceans of the present day. On the contrary, it seems very possible that certain of the sediments of such old systems as the Cambrian and Ordovician were formed at great depths, and that they represent the modern abyssal clays. This is particularly the case with some of the fine-grained, red, brown, or green muds which occasionally form a conspicuous feature in the Cambrian and Ordovician series. Such muds are not only singular for their extraordinary barrenness in fossils, but there is good ground for thinking that they have been formed by the decomposition of volcanic matter, while they commonly exhibit dendrites of manganese.

IV. Disappearance of Fossils.—The last subject which need be mentioned in connection with the imperfection of the palæontological record, is that of the disappearance of fossils from rocks originally fossiliferous. This, as a rule, is due to "metamorphism"—that is to say, the subjection of the rock to a sufficient amount of pressure or heat to cause a rearrangement of its particles. When of at all a pronounced character, the result of metamorphism is the more or less complete obliteration of any fossils which might have been originally present in the rock. To this cause must be set down many great gaps in the palæontological record, and the irreparable loss of much fossil evidence.

Another not uncommon cause of the disappearance of organic remains from originally fossiliferous deposits is the percolation through

them of water holding carbonic acid in solution. By this means fossils of a calcareous nature are dissolved out of the rock, and may leave no traces behind. This cause, however, can only operate to any extent in more or less loose and porous arenaceous deposits.

Lastly, "cleavage" may be mentioned as a common cause of the disappearance of fossils. But the cleavage must be very intense, if it actually prevents the recognition of the deposit as one in which fossils formerly existed, though cases are not uncommon in which this occurs through thousands of feet of strata. As a more general rule, however, it is not very difficult to determine whether a cleaved rock has ever contained fossils or not, though it may be quite impossible to make out the exact nature and character of the organic remains.

CHAPTER V.

CONCLUSIONS TO BE DRAWN FROM FOSSILS.

We have already seen that geologists have been led by the study of fossils to the all-important generalisation that the vast series of the Fossiliferous or Sedimentary rocks may be divided into a number of definite groups or "systems," each of which is characterised by its organic remains. It may simply be repeated here that these systems are not properly and strictly characterised by the occurrence in them of any one particular fossil. It very often happens, indeed, that some particular stratum, or sub-group of a series, contains peculiar fossils, by which its existence may be determined in various localities. As before remarked, however, the great systems are characterised properly by the association of certain fossils, by the predominance of certain families or orders, or by an *assemblage* of fossil remains representing the "life" of the period in which the system was deposited.

Fossils, then, enable us to determine the *age* of the deposits in which they occur. Fossils further enable us to come to very important conclusions as to the mode in which the fossiliferous bed was deposited, and thus as to the condition of the particular district or region occupied by the fossiliferous bed at the time of the formation of the latter. If, in the first place, the bed contain the remains of animals such as now inhabit rivers, we know that it is "fluviatile" in its origin, and that it must at one time have either formed an actual river-bed, or been deposited by the overflowing of an ancient stream. Secondly, if the bed contain the remains of shell-fish, minute crustaceans, or fish, such as now inhabit lakes, we know that it is "lacustrine," and was deposited beneath the waters of a former lake. Thirdly, if the bed contain the remains of animals such as now people the ocean, we know that it is "marine" in its origin, and that it is a fragment of an old sea-bottom.

We can, however, often determine the conditions under which a bed was deposited with greater accuracy than this. If, for example,

the fossils are of kinds resembling the marine animals now inhabiting shallow waters, if they are accompanied by the detached relics of terrestrial organisms, or if they are partially rolled and broken, we may conclude that the fossiliferous deposit was laid down in a shallow sea, in the immediate vicinity of a coast-line, or as an actual shore-deposit. If, again, the remains are those of animals such as now live in the deeper parts of the ocean, and there is a very sparing intermixture of extraneous fossils (such as the bones of birds or quadrupeds, or the remains of plants), we may presume that the deposit is one of deep water. In other cases, we may find, scattered through the rock, and still in their natural position, the valves of shells such as we know at the present day as living buried in the sand or mud of the sea-shore or of estuaries. In other cases, the bed may obviously have been an ancient coral-reef, or an accumulation of social shells, like Oysters. Lastly, if we find the deposit to contain the remains of marine shells, but that these are dwarfed of their fair proportions and distorted in figure, we may conclude that it was laid down in a brackish sea, such as the Baltic, in which the proper saltness was wanting, owing to its receiving an excessive supply of fresh water.

In the preceding, we have been dealing simply with the remains of aquatic animals, and we have seen that certain conclusions can be accurately reached by an examination of these. As regards the determination of the conditions of deposition from the remains of aerial and terrestrial animals, or from plants, there is not such an absolute certainty. The remains of land-animals would, of course, occur in "sub-aerial" deposits—that is, in beds, like blown sand, accumulated upon the land. Most of the remains of land-animals, however, are found in deposits which have been laid down in water, and they owe their present position to having been drowned in rivers or lakes, or carried out to sea by streams. Birds, flying Reptiles, and flying Mammals might also similarly find their way into aqueous deposits; but it is to be remembered that many Birds and Mammals habitually spend a great part of their time in the water, and that these might therefore be naturally expected to present themselves as fossils in Sedimentary rocks. Plants, again, even when undoubtedly such as must have grown on land, do not prove that the bed in which they occur was formed on land. Many of the remains of plants known to us are extraneous to the bed in which they are now found, having reached their present site by falling into lakes or rivers, or being carried out to sea by floods or gales of wind. There are, however, many cases in which plants have undoubtedly grown on the very spot where we now find them. Thus it is now generally admitted that the great coal-fields of the Carboniferous age are the result of the growth *in situ* of the plants which compose coal,

and that these grew on vast marshy or partially submerged tracts of level alluvial land. We have, moreover, distinct evidence of old land-surfaces, both in the Coal-measures and in other cases (as, for instance, in the well-known "dirt-bed" of the Purbeck series). When, for example, we find the erect stumps of trees standing at right angles to the surrounding strata, we know that the surface through which these send their roots was at one time the surface of the dry land, or, in other words, was an ancient soil (fig. 17).



Fig. 17.—Erect Tree containing Reptilian remains. Coal-measures, Nova Scotia. (After Dawson.)

Conclusions as to Climate.—In many cases fossils enable us to come to important conclusions as to the climate of the period in which they lived, but only a few instances of this can be here adduced. As fossils in the majority of instances are the remains of marine animals, it is mostly the temperature of the sea which can alone be determined in this way; and it is important to remember that, owing to the existence of heated currents, the marine climate of a given area does not necessarily imply a correspondingly warm climate in the neighbouring land. Land-climates can only be determined by the remains of land-animals or land-plants, and these are comparatively rare as fossils. It is also important to remember that all conclusions on this head are really based upon the present distribution of animal and vegetable life on the globe, and are therefore liable to be vitiated by the following considerations:—

a. Most fossils are extinct, and it is not certain that the habits and requirements of any extinct animal were exactly similar to, or even at all resembling, those of its nearest living relative.

b. When we get very far back in time, we meet with groups of organisms so unlike anything we know at the present day as to render all conjectures as to climate founded upon their supposed habits more or less uncertain and unsafe.

c. In the case of marine animals, we are as yet very far from knowing the exact limits of distribution of many species within our present seas; so that conclusions drawn from living forms as to extinct species are apt to prove incorrect. For instance, it has

recently been shown that many shells formerly believed to be confined to the arctic seas have, by reason of the extension of polar currents, a wide range to the south; and this has thrown doubt upon the conclusions drawn from fossil shells as to the arctic conditions under which certain beds were supposed to have been deposited.

d. The distribution of animals at the present day is certainly dependent upon other conditions beside climate alone; and the causes which now limit the range of given animals are certainly such as belong to the existing order of things. But the establishment of the present order of things does not date back in many cases to the introduction of the present species of animals. Even in the case, therefore, of existing species of animals, it can often be shown that the past distribution of the species was different formerly to what it is now, not necessarily because the climate has changed, but because of the alteration of other conditions essential to the life of the species or conducing to its extension.

Upon the whole, therefore, it would seem that conclusions as to the climate of any particular area at any given point of geological time must be accepted with considerable caution, unless in cases where there happens to be direct *physical* evidence of an arctic climate. It has, in fact, been even questioned that there existed marked differences in the climate of different regions of the earth in the earlier periods of the earth's history. Rather, it has been held that in ancient geological times an equable temperature reigned over the whole globe, as the result of a relatively high internal terrestrial heat, the earth's surface and the air being thus maintained at a temperature sufficiently high to render the influence of the sun's rays of comparatively little importance. On this view it was supposed that it was only when the earth's internal heat had been largely dissipated by radiation, that climatic zones were developed; the temperature of each region coming ultimately to depend mainly upon the amount of heat which it might receive, directly or indirectly, from the sun. The change from the one condition of things to the other was usually supposed to have corresponded, in a general way, with the commencement of the Tertiary period.

Apart, however, from the inherent improbabilities attaching to this theory—so far, at any rate, as concerns the periods subsequent to the introduction of animal and vegetable life upon the globe—it has been shown by Professor Neumayr that the existence of definite climatic zones can be demonstrated, by the evidence of fossils, in periods at least as ancient as the Jurassic. As regards the Palæozoic period, the principal argument for the assumption that the earth enjoyed a uniformly high temperature, as pointed out by Neumayr, is that the Palæozoic animals, even in northern latitudes,

are often more nearly related to types now living in the tropics than to any others. As regards certain types—such as the ancient and persistent genus *Nautilus*—some weight may be reasonably attached to this argument. Another argument for the assumed uniformity of climate in Palæozoic time may be based upon the extraordinarily wide range in space of many Palæozoic types of animals. Upon the whole, however, the Palæozoic animals differ so widely from their nearest living relatives as to render it very hazardous to base on their supposed habits of life any decided conclusions as to Palæozoic climate. Much the same may be said with regard to the argument in favour of a very uniform and widely spread warm-temperate climate during Carboniferous times, based upon the extension of the predominant Coal-plants to high northern latitudes.

Taken collectively, our knowledge would rather go to show that considerable variations in climate have occurred in all periods subsequent to the appearance of living beings upon the earth. Thus, there is more or less weighty evidence in favour of the occurrence of Glacial periods in various of the older formations, beginning as early as the Cambrian period. In Mesozoic time, certainly, the evidence adduced by Neumayr, Marcou, and Trautschold seems to show conclusively that different regions of the earth enjoyed, as they do at present, different climates. The first of these observers, in particular, has shown that a study of the animal life of the Jurassic deposits of the north hemisphere would support the conclusion that there existed during the Jurassic period three well-marked climatic zones—one boreal, one temperate, and one subtropical—and that two of these, at any rate, can be recognised in the south hemisphere also.

CHAPTER VI.

RELATIONS OF PALÆONTOLOGY TO GEOLOGY AND BIOLOGY—METHODS OF PALÆONTOLOGY—CLASSIFICATION OF THE ANIMAL KINGDOM.

In more than one of its aspects, Palæontology stands in an intimate relation with *Geology*. Thus, so far as it is concerned with investigating the mode of life and distribution in *space* of fossil organisms, Palæontology becomes directly connected with the physiographical side of Geology. From another point of view, in so far as it investigates the relations of fossil organisms to *time*, Palæontology becomes closely interwoven with Historical or Stratigraphical Geology. In all its fundamental aspects, however, Palæontology is essentially a branch of *Biology*—constituting a branch of *Zoology* where it deals with animals, and of *Botany* in so far as it deals with plants. Palæontology, therefore, may be properly divided into the two departments of "Palæozoology" and "Palæobotany." The principal ground for the use of the separate term "Palæontology," as distinct from "Zoology" and "Botany," is simply that in studying extinct organisms we have to take into account *the time at which these lived*. It is therefore the element of time, and that alone, which entitles us to speak of Palæontology as an independent science.

The *methods* of palæontological study are precisely the same as those of Zoology and Botany. It is true that the earlier palæontologists attached a certain importance to the *age* of a fossil, as bearing upon the determination of its affinities, and that it was sometimes assumed that fossils from deposits of different geological ages were necessarily referable to different specific types. At the present day, however, it is recognised that the systematic position and relationships of an extinct organism must be settled by an appeal to its *morphological* characters, altogether or to a great extent irrespective of the age of the deposit in which it occurs. The zoologist and the

botanist similarly rely essentially upon Morphology in the determination of the relations of animals and plants; and there is, therefore, no real difference in the methods of study employed, whether the organisms under examination be living or extinct.

In some respects, however, the zoologist has a great advantage over the palæontologist. The student of living beings can investigate the *entire* organism, the soft parts as well as the hard; and he can also study the "development" of the organism, and by tracing it through its early stages can discover how it came to assume its adult characters. The student of fossil organisms, on the other hand, is restricted, with the rarest exceptions, to an investigation of the *hard parts* only. The conclusions of the palæontologist as to the characters and affinities of fossil animals are necessarily based upon a study of the skeletal structures, from which the characters of the soft parts have to be inferred. Moreover, it commonly happens that even the hard parts of the animal have been imperfectly preserved, and that the object to be studied is a mere fragment of the skeleton, from which all the soft tissues have been removed. Again, it is only in exceptional cases that we have any means of making ourselves acquainted with the development of fossil animals. Considering the generally fragmentary character of the objects with which the palæontologist has to deal, and the almost invariable absence in fossils of any traces of the soft parts of the organism, it might be supposed that the study of fossils was attended with insuperable difficulties. The most serious of these difficulties are, however, overcome by means of the law of the "correlation of organs," the establishment of which by the illustrious Cuvier marks an era in palæontological science.

Stated in its most general form, the law of the correlation of organs is the law that all the parts of an organism stand in some relation to one another, the form and characters of each part being more or less closely dependent on, and connected with, the form and characters of all the rest. In other words, an organism is not a fortuitous collocation of unrelated parts, but is composed of mutually adapted and related organs, the possession of any given organ, therefore, implying the possession of other "correlated" organs. Thus, the possession of mammary glands is "correlated" with the possession of two occipital condyles and of a simple mandible; a stomach adapted for rumination is correlated with the possession of only two functional toes to the foot, and the absence of the central upper incisors; an inflected angle of the lower jaw is usually correlated with the possession of "marsupial bones" or "marsupial cartilages"; a covering of feathers is correlated (in living forms) with saddle-shaped faces to the bodies of the cervical vertebræ. From the above examples it will be evident that, by means of the law of correlation, it

is often possible to infer from an isolated organ or structure the essential characters of the remainder of the organism. Thus, if we were acquainted with no other part of some animal than its skull alone, and if we found that that skull possessed two occipital condyles, and that each half of the lower jaw was composed of a single piece, we should be justified in concluding that the animal to which the skull belonged possessed mammary glands. We should also be justified in inferring many other facts about it, as, for example, that it possessed (or might have possessed) a hairy covering to the body, that its blood was hot, and that it possessed non-nucleated red blood-corpuscles. Similarly, if we met with a mammalian lower jaw, the angle of which was bent inwards, or "inflected," we should have a strong presumption that the animal to which it belonged possessed "marsupial bones" or cartilages on the brim of the pelvis, and that the young were born in a very imperfect state of development. It follows from what has been already said, that the law of the correlation of organs plays a most important part in palæontological investigation, enabling the observer to more or less completely "reconstruct" an extinct organism by means of its fragmentary remains. It is to be remembered, however, that the law is a purely empirical one, and expresses nothing more than the result of experience; so that structures which we now know only as occurring in association may ultimately be found separate, and conjoined with structures of a different character.[1] Moreover, it is to be borne in mind that in any two correlated structures it is not that *each* is correlated with the other, but that *one* of the two is correlated with the other. That is to say, of any two correlated organs, A and B, it may be true that A is never found without B, but it does not follow that B may not occur without A. Thus, the presence of a stomach adapted for "rumination" is invariably associated (in living types) with an imperfect development of the incisors of the upper jaw, the central upper incisors being always wanting; but it is not the case that an incomplete condition of the upper incisors, or the absence of the central ones, is necessarily correlated with the habit of chewing the cud. The proper way of putting the case is to assert that certain structures (A) are never found apart from other structures (B), though the latter may be present without the former. When, therefore, we find a lower jaw having its angle "inflected," we may, with our present knowledge, assert that the animal to which that jaw belonged probably possessed "marsupial bones" or "marsupial cartilages" upon the brim of the pelvis; although the presence of a certain amount of inflection in the jaws of some *Insectivora* would preclude

[1] A remarkable instance where this correlation is at fault, and has led to the reference of the bones of one animal to two distinct orders, will be noticed among the *Mammalia* under the head of *Chalicotherium*.

our making this assertion absolutely positive. If, however, we were to find a pelvis with marsupial bones, we should not be justified in asserting that the owner of the same must have possessed an inflected angle to the lower jaw. On the contrary, we know that such an assertion would be erroneous, since the "marsupial bones" are present in the Monotremes, in which the angle of the jaw has its usual form.

Classification of the Animal Kingdom.

Vast as is the number of known animals, all, whether living or extinct, may be classed under a limited number of primary divisions or "morphological types," which are technically spoken of as the "sub-kingdoms." There are also certain groups of animals (the Molluscoids and Tunicates) which have not the value of "sub-kingdoms," but which are so far separated by their characters from their nearest relatives that it is expedient in the meanwhile to treat them as constituting distinct divisions of the animal kingdom. All the animals in any one sub-kingdom agree with one another in their structural type, or in the fundamental plan upon which they are constructed, and they differ from one another simply in the modifications of this common plan. Two animals belonging to different sub-kingdoms may be rendered closely similar to one another as the result of similar adaptive modifications, but no amount of physiological likeness will counterbalance or efface the morphological unlikeness due to the fact that each is constructed upon an essentially different ground-plan. As the animals belonging to any given sub-kingdom are separated solely by the characters due to varying modifications of a common morphological type, it is possible to arrange the members of each in an approximately linear series, in which the lowest members most closely approach the primitive or ideal form of the sub-kingdom, while the highest exhibit the greatest amount of complexity and specialisation of this type. But it is not possible to establish any such linear classification for the animal kingdom as a whole. Given an animal of a lower "sub-kingdom" than another animal, no amount of complexity, no specialisation of organisation, can raise the former above the latter. The one may be the result of the high evolution of a low morphological type, the other may be the result of the low evolution of a higher morphological type, but the superiority of the ground-plan gives the latter the higher place. It is obvious, therefore, that a linear classification is not possible; since the higher members of each sub-kingdom are more highly organised than the lower forms of the next sub-kingdom in the series, at the same time that they are constructed upon a lower morphological type.

It is, in fact, clear that a pictorial representation of the different groups of the animal kingdom, in the order of their natural alliances, would not exhibit a series of regularly ascending steps, but would have the form of a branched and ramified genealogical tree. Such a tree would exhibit one main stem, which would give origin to numerous lateral stems. These latter would, in turn, subdivide, some branches ascending in the course of their development, while others, as the result of degeneration, would descend.

The terms "class," "order," "genus," "sub-genus," "species," and "variety," are employed by the palæontologist in precisely the same sense, and with precisely the same limitations, as by the zoologist. We must notice, however, that a *palæontological* "species" has not always or necessarily the same value as that which a *zoological* species ought invariably to possess. This arises from the fact that the determination of fossil species is, almost without exception, based solely upon the characters of the hard parts of the animal—these, also, being often but imperfectly preserved. A fossil species, therefore, cannot, from the nature of things, be as thoroughly defined as a living one; and it is both possible and probable that variations in the form of the skeleton, especially if an integumentary one, may often depend upon mere individual, sexual, or local peculiarities, which could be at once discovered in the case of living forms, but which can hardly be detected as regards extinct types. Moreover, there is a practical inconvenience attending the use of the terms "variety" and "sub-genus" in palæontology, which is not found in zoology, owing to the very different nature of the working material of these two sciences. Many palæontologists, therefore, prefer, as we think rightly, to follow the general practice of giving distinct names to "varieties" and "sub-genera," thus practically raising them to the rank of "species" and "genera"; and this practice can hardly be injurious if accompanied with the well-understood reservation that this is done as a matter of convenience only, and that a somewhat wider and looser signification is to be given to the terms "species" and "genus" in palæontology than would be admissible in zoology. At the same time, this practice may be, and has been, carried too far; and in the case of very variable or "protean" species, it is certainly advisable to adhere to the plan usually adopted by British palæontologists—namely, to define the species by its central type, and to group the variable forms under this type as varieties. As a general definition, however, of what is understood in palæontology as a species, we may follow Zittel. This distinguished naturalist defines a palæontological "species" as comprising "all those individuals, or remains of individuals, which possess in common an assemblage of constant characters, and which constitute collectively a distinctly circumscribed morphological series ("For-

menkreis "), apart from all considerations relating to their range in time and in space." Such a series may be connected by transitional forms with other morphological groups without losing its claim to be considered as constituting a "species," provided the series does not shade off in all directions into allied groups.

The following synoptical table gives the leading divisions of the animal kingdom, with typical examples of each. Forms marked with an asterisk are extinct, and are only known in the fossil condition :—

TABULAR VIEW OF THE CHIEF DIVISIONS OF THE ANIMAL KINGDOM.

INVERTEBRATE ANIMALS.

SUB-KINGDOM I.—PROTOZOA.

CLASS I.—GREGARINIDA.

Gregarina, Monocystis. No fossil forms of this class exist.

CLASS II.—RHIZOPODA.

1. MONERA	*Protamœba.* No fossil forms.
2. AMŒBEA	*Amœba, Difflugia, Arcella.* No fossil forms.
3. FORAMINIFERA	*Gromia, Biloculina, Saccammina, Lituola, Textularia, Lagena, Globigerina, Rotalia, *Orbitoides, Nummulina.*
4. RADIOLARIA	*Thalassicolla, Acanthometra, Podocyrtis, Eucyrtidium.*
5. HELIOZOA	*Actinophrys, Actinosphærium.* No fossil forms.

CLASS III.—INFUSORIA.

1. CILIATA	*Paramœcium.* No fossil forms.
2. SUCTORIA	*Acineta.* No fossil forms.
3. FLAGELLATA	*Codosiga.* No fossil forms.
4. CILIO-FLAGELLATA	*Ceratium, Peridinium.* Doubtful fossil representatives are known.

SUB-KINGDOM II.—PORIFERA.

CLASS I.—PLETHOSPONGIÆ.

1. MYXOSPONGIÆ	*Halisarca.* No fossil forms.
2. CERATOSPONGIÆ	*Euspongia.* Fossil representatives of doubtful occurrence.
3. MONACTINELLIDÆ	*Spongilla, Cliona, *Scoliorhaphis.*
4. TETRACTINELLIDÆ	*Tethya, Geodia, Pachastrella, *Tethyopsis.*
5. LITHISTIDÆ	*Discodermia, Corallistes, *Chenendopora, *Doryderma, *Aulocopium, *Siphonia, *Jerea, *Astylospongia.*
6. HEXACTINELLIDÆ	*Holtenia, Euplectella, Hyalonema, *Ventriculites, *Protospongia, *Cœloptychium.*

7. *Octactinellidæ . . *Astræospongia.*
8. *Heteractinellidæ . *Tholiasterella, Asteractinella.*

CLASS II.—CALCISPONGIÆ.

1. Homocœla . . . *Leucosolenia.* No fossil forms known. (=*Ascones* of Haeckel).
2. Heterocœla . . . *Grantia, Sycon,* **Protosycon* (=*Sycones* of Haeckel), *Leuconia, Leucandra,* &c. (=*Leucones* of Haeckel), **Corynella,* **Sestrostomella,* **Pharetrospongia* (*Pharetrones*).

SUB-KINGDOM III.—CŒLENTERATA.

CLASS I.—HYDROZOA.

Sub-class I.—Hydroida (Hydroid Zoophytes).

1. Hydrida *Hydra.* No fossil forms.
2. Corynida *Coryne, Tubularia, Hydractinia,* **Parkeria.*
3. Thecaphora . . . *Sertularia, Plumularia, Campanularia,* **Dendrograptus* (?), **Callograptus* (?).
4. Trachymedusæ . . *Trachynema, Ægina,* **Palægina.*

Sub-class II.—Siphonophora.

1. Calycophoridæ . . *Diphyes.* No fossil forms.
2. Physophoridæ . . . *Physalia.* No fossil forms.

Sub-class III.—Lucernarida.

1. Calycozoa *Lucernaria.* No fossil forms.
2. Acraspeda (Discophora) . *Aurelia, Rhizostoma,* **Rhizostomites.*

* Sub-class IV.—Graptolitoidea.

1. Monoprionidæ . . . *Monograptus, Didymograptus, Tetragraptus.*
2. Diprionidæ . . . *Diplograptus, Climacograptus, Retiolites, Phyllograptus.*

Sub-class V.—Hydrocorallinæ.

a. Milleporidæ . . . *Millepora,* **Axopora.*
b. Stylasteridæ . . . *Stylaster, Allopora.*
c. * Syringosphæridæ . . *Syringosphæra, Stoliczkaria.*

* Sub-class VI.—Stromatoporoidea.

Stromatopora, Actinostroma, Labechia.

CLASS II.—ACTINOZOA.

1. Zoantharia.
 - *A.* Actiniaria (Zoantharia malacodermata) . . *Actinia.* No fossil forms.
 - *B.* Antipatharia (Zoantharia sclerobasica) . *Antipathes.*
 - *C.* Madreporaria (Zoantharia sclerodermata).
 - *a.* Aporosa . . *Turbinolia, Oculina, Pocillopora, Mæandrina,* **Columnaria,* **Stauria,* **Holocystis, Moseleya.*
 - *b.* Rugosa . . **Cyathophyllum,* **Zaphrentis,* **Cystiphyllum.*

c. Fungida . . *Fungia,* **Anabacia.*
d. Perforata . . *Madrepora, Porites,* **Favosites,* **Syringopora,* **Thecia.*

2. ALCYONARIA
a. Haimeidæ . . . *Monoxenia, Hartea.* No fossil forms.
b. Cornulariadæ . . *Cornularia.* No fossil forms.
c. Alcyonidæ . . . *Alcyonium.* No fossil forms.
d. Pseudaxonia . . *Corallium, Mopsea.*
e. Tubiporidæ . . *Tubipora.* No fossil forms.
f. Helioporidæ . . *Heliopora.*
g. Gorgonidæ . . . *Gorgonia, Gorgonella, Isis, Primnoa.*
h. Pennatulidæ . . *Pennatula,* **Graphularia.*
i. *Heliolitidæ . . *Heliolites, Plasmopora.*
j. *Halysitidæ . . *Halysites.*
k. *Tetradiidæ . . *Tetradium.*
l. *Chætetidæ . . *Chætetes.*
m. *Auloporidæ . . *Aulopora, Cladochonus.*

3. *MONTICULIPOROIDEA. (Zoological affinities uncertain).
a. Monticuliporidæ . . *Monticulipora.*
b. Fistuliporidæ . . *Fistulipora, Callopora.*

4. CTENOPHORA . . . *Pleurobrachia, Beroe.* No fossil forms.

SUB-KINGDOM IV.—ECHINODERMATA.

DIVISION A.—ECHINOZOA.

CLASS I.—ECHINOIDEA.

1. *PALECHINOIDEA . . *Archæocidaris, Bothriocidaris.*
2. EUECHINOIDEA . . . *Echinus, Cidaris, Spatangus,* **Echinothuria.*

CLASS II.—ASTEROIDEA.

1. *ENCRINASTERIÆ . . *Palæaster, Petraster.*
2. ASTERIÆ VERÆ . . . *Asterias, Goniaster, Solaster.*

CLASS III.—OPHIUROIDEA.

1. EURYALIDA . . . *Asterophyton,* **Onychaster.*
2. OPHIURIDA . . . *Ophioglypha,* **Aspidura.*

CLASS IV.—HOLOTHUROIDEA.

Cucumaria, Psolus.

DIVISION B.—PELMATOZOA.

CLASS I.—CRINOIDEA.

1. *PALÆOCRINOIDEA . . *Actinocrinus, Cyathocrinus.*
2. NEOCRINOIDEA . . . *Pentacrinus,* **Encrinus, Antedon.*

CLASS II.—*CYSTOIDEA.

1. APORITIDÆ . . . *Cryptocrinus, Agelacrinus.*
2. DIPLOPORITIDÆ . . . *Glyptosphærites, Sphæronites.*
3. RHOMBIFERI . . . *Echinosphærites, Caryocrinus.*

CLASS III.—*BLASTOIDEA.

1. REGULARES . . . *Pentremites, Granatocrinus, Codaster.*
2. IRREGULARES . . . *Astrocrinus, Eleutherocrinus.*

SUB-KINGDOM V.—ANNULOSA.

DIVISION I.—SCOLECIDA.

CLASS I.—PLATYELMIA (Flat-worms).

1. TÆNIADA *Tænia.* No fossil forms.
2. TREMATODA . . . *Distoma.* No fossil forms.
3. TURBELLARIA . . . *Planaria, Nemertes.* No fossil forms.

CLASS II.—NEMATELMIA (Round-worms).

1. ACANTHOCEPHALA . . *Echinorhynchus.* No fossil forms.
2. GORDIACEA *Gordius.* No fossil forms.
3. NEMATOIDEA . . . *Ascaris.* No fossil forms.

CLASS III.—ROTIFERA (ROTATORIA).

The Wheel-animalcules are wholly unknown in the fossil condition.

DIVISION II.—ANARTHROPODA.

CLASS I.—GEPHYREA (Spoon-worms).

With the very doubtful exception of the Jurassic genus *Epitrachys*, no representative of the Spoon-worms is known in the fossil condition. Well-known recent genera are *Sipunculus* and *Echiurus*.

CLASS II.—MYZOSTOMIDA.

The type-genus is *Myzostoma.* (Recent and fossil).

CLASS III.—ANNELIDA (Ringed-worms).

1. HIRUDINEA . . . *Sanguisuga, Clepsine.* No fossil forms.
2. OLIGOCHÆTA . . . *Lumbricus* (Earth-worm). Not certainly known in the fossil condition.
3. POLYCHÆTA.
 a. Tubicola . . . *Serpula, Spirorbis, *Cornulites.*
 b. Errantia . . . *Nereis, Aphrodite, *Eunicites, *Arabellites.*

CLASS IV.—CHÆTOGNATHA (Arrow-worms).

This class comprises the single recent genus *Sagitta*, and has no fossil representatives.

DIVISION III.—ARTHROPODA.

CLASS I.—CRUSTACEA.

Sub-class I.—Anchoracephala.

1. CIRRIPEDIA . . . *Lepas* (Barnacle), *Balanus* (Acorn-shell), **Turrilepas.*
2. RHIZOCEPHALA . . . *Peltogaster, Sacculina.* No fossil forms.

Sub-class II.—Entomostraca.

1. OSTRACODA . . . *Cypris, Cypridina, *Beyrichia, *Primitia.*
2. COPEPODA *Cyclops, Lernæa, Argulus.* No fossil forms.
3. CLADOCERA . . . *Daphnia.* No fossil forms.
4. PHYLLOPODA . . . *Apus, Estheria, Branchipus.*
5. PHYLLOCARIDA . . *Nebalia, *Hymenocaris, *Ceratiocaris, *Discinocaris.*

Gigantostraca
- 6. *Trilobita — *Asaphus, Calymene, Illænus.*
- 7. Xiphosura — *Limulus* (King-crab), **Belinurus.*
- 8. *Eurypterida — *Eurypterus, Pterygotus.*

Sub-class III.—Malacostraca.

1. Amphipoda — *Talitrus, Gammarus, *Prosoponiscus.*
2. Isopoda — *Idotea, Oniscus, Serolis, *Archæoniscus.*
3. Stomatopoda — *Squilla* (Locust-shrimp).
4. Schizopoda — *Mysis* (Opossum-shrimp).
5. Cumacea — *Diastylis.*
6. Decapoda.
 - *a.* Macrura — *Homarus* (Lobster).
 - *b.* Anomura — *Pagurus* (Hermit-crab).
 - *c.* Brachyura — *Cancer* (Crab).

CLASS II.—ARACHNIDA.

1. Podosomata (Pycnogonida) — *Pycnogonum, Nymphon.* No fossil forms.
2. *Anthracomarti — *Arthrolycosa, Architarbus, Anthracomartus.*
3. Acarina — *Acarus, Ixodes, Hydrachna.*
4. Adelarthrosomata — *Phalangium, Chelifer, Galeodes.*
5. Pedipalpi — *Scorpio, *Palæophonus, *Proscorpius.*
6. Araneida — *Tegenaria, Epeira, *Protolycosa.*

CLASS III.—MYRIOPODA.

1. Onychophora — *Peripatus.* No fossil forms.
2. Pauropoda — *Pauropus.* No fossil forms.
3. *Protosyngnatha — *Palæocampa.*
4. Chilopoda — *Scolopendra, Lithobius, Geophilus.*
5. *Archipolypoda — *Archidesmus, Euphoberia, Archiulus, Xylobius.*
6. Diplopoda (Chilognatha) — *Iulus, Polydesmus.*

CLASS IV.—INSECTA.

1. Anoplura — *Pediculus.* No fossil forms.
2. Mallophaga — *Trichodectes.* No fossil forms.
3. Collembola — *Podura.*
4. Thysanura — *Lepisma, Petrobius.*
5. *Palæodictyoptera — *Eugereon, Dictyoneura, Palæoblattina.*
6. Rhynchota (Hemiptera) — *Nepa, Cicada, Notonecta.*
7. Othoptera — *Blatta, Mantis, Gryllus, Œdipoda, Forficula.*
8. Neuroptera.
 - *a.* Pseudoneuroptera — *Libellula, Termes, Ephemera.*
 - *b.* Neuroptera Vera — *Myrmeleon, Hemerobius, Panorpa.*
 - *c.* Trichoptera — *Phryganea, Limnophilus.*
9. Aphaniptera — *Pulex.* No fossil forms.
10. Diptera — *Culex, Musca, Tipula.*
11. Lepidoptera — *Vanessa, Sphinx, Bombyx.*
12. Hymenoptera — *Apis, Vespa, Formica.*
13. Strepsiptera — *Stylops, *Triæna.*
14. Coleoptera — *Melolontha, Carabus, Cicindela.*

MOLLUSCOIDEA.

CLASS I.—POLYZOA.

Sub-class I.—Ectoprocta.

1. Phylactolæmata — *Plumatella.* No fossil forms.
2. Gymnolæmata.
 - *a.* Cyclostomata — *Tubulipora, Diastopora, *Fenestella, *Ptilodictya.*

b. Cheilostomata . . *Cellepora, Eschara, Lepralia, Flustra, Bugula.*
c. Ctenostomata . . *Vesicularia, Alcyonidium.* No fossil forms.

Sub-class II.—Entoprocta.

Loxosoma, Pedicellina. No fossil forms.

Sub-class III.—Aspidophora.

Rhabdopleura. No fossil forms.

CLASS II.—BRACHIOPODA.

1. INARTICULATA . . . *Crania, Discina, Lingula, *Lingulella, *Acrotreta.*
2. ARTICULATA . . . *Terebratula, Rhynchonella, *Spirifera, *Strophomena, *Orthis, *Producta.*

SUB-KINGDOM VI.—MOLLUSCA.

CLASS I.—LAMELLIBRANCHIATA (CONCHIFERA or PELECYPODA).

1. OSTREACEA . . . *Ostrea, *Gryphæa, Anomia.*
2. PECTINACEA . . . *Spondylus, Lima, Pecten.*
3. MYTILACEA . . . *Avicula, *Aviculopecten, Mytilus, Pinna.*
4. ARCACEA *Arca, Pectunculus, Nucula.*
5. SUBMYTILACEA . . . **Modiolopsis, Trigonia, Unio, Astarte, Crassatella.*
6. ERYCINACEA . . . **Erycina, Galeomma.*
7. CARDIACEA . . . *Tridacna, Cardium, *Lunulicardium.*
8. CHAMACEA . . . *Chama, *Diceras, *Caprina, *Hippurites.*
9. CONCHACEA . . . **Megalodon, Cyprina, Venus, Cyrena, Psammobia, Solen, Donax.*
10. MYACEA *Mactra, Mya, Glycimeris, Gastrochæna.*
11. ADESMACEA . . . *Pholas, Teredo.*
12. LUCINACEA . . . *Lucina, Corbis.*
13. TELLLINACEA . . . *Tellina, Scrobicularia.*
14. ANATINACEA . . . *Solemya, Anatina, Pholadomya, Clavagella.*

CLASS II.—GASTROPODA.

Sub-Class I.—Branchiogastropoda.

1. PROSOBRANCHIATA . . *Buccinum, Strombus, Littorina, Natica, *Murchisonia.*
2. OPISTHOBRANCHIATA . . *Actæon, Bulla, Aplysia, Doris.*
3. PTEROPODA.
 a. Gymnosomata . . *Clio, Pneumodermon.* No fossil forms.
 b. Thecosomata . . *Cavolinia, Cleodora, *Hyolithes, *Tentaculites.*
4. HETEROPODA . . . *Carinaria, Atlanta.*

Sub-class II.—Pulmogastropoda.

1. STYLOMMATOPHORA . . *Helix, Limax.*
2. BASOMMATOPHORA . . *Limnæa, Planorbis.*

CLASS III.—POLYPLACOPHORA.

1. CHITONIDÆ . . . *Chiton, *Helminthochiton.*

CLASS IV.—SCAPHOPODA.

1. SOLENOCONCHIA . . . *Dentalium.*

CLASS V.—CEPHALOPODA.

1. DIBRANCHIATA . . .	*Loligo, Sepia, Spirula, Octopus, * Belemnites.*
2. TETRABRANCHIATA . .	*Nautilus, * Orthoceras, * Ammonites, * Baculites.*

TUNICATA.

[The Tunicates or Ascidians occupy a position intermediate between *Mollusca* and *Vertebrata*. No fossil forms are known, except in late Tertiary deposits.]

VERTEBRATE ANIMALS.[1]

SUB-KINGDOM VII.—VERTEBRATA.

CLASS I.—LEPTOCARDIA.

PHARYNGOBRANCHEI . .	*Branchiostoma* (*Amphioxus*). No fossil forms.

CLASS II.—PISCES (FISHES).

1. CYCLOSTOMI (MARSIPOBRANCHII . . .	*Myxine, Petromyzon.* No fossil forms.
2. ELASMOBRANCHEI.	
a. * Ichthyotomi . .	*Pleuracanthus.*
b. Selachii	
(1) Tectospondyli .	*Cestracion, Lamna, Spinax.*
(2) Asterospondyli .	*Squatina, Raia.*
3. CHIMÆROIDEI . . .	*Chimæra, * Ischiodus.*
4. DIPNOI	*Lepidosiren, Ceratodus.*
5. GANOIDEI.	
a. * Cephalaspidea . .	*Cephalaspis, Pteraspis.*
b. * Placodermata . .	*Pterichthys, Coccosteus.*
c. * Acanthodea . .	*Acanthodes, Diplacanthus.*
d. Crossopterygea . .	** Holoptychius, Polypterus.*
e. Acipenseroidea . .	*Acipenser, * Palæoniscus.*
f. Lepidosteoidea . .	*Lepidosteus, * Dapedius.*
g. Amioidea . . .	*Amia, * Caturus.*
6. TELEOSTEI.	
a. Physostomi . . .	*Salmo, Esox, Silurus.*
b. Anacanthini . . .	*Gadus, Rhombus.*
c. Pharyngognathi . .	*Labrax, * Phyllodus.*
d. Acanthopterygii . .	*Mugil, Perca.*
e. Lophobranchii . .	*Solenostoma, Hippocampus.*
f. Plectognathi . . .	*Balistes, Diodon.*

CLASS III.—AMPHIBIA (AMPHIBIANS).

1. * LABYRINTHODONTIA.	
a. Branchiosauria . .	*Protriton.*
b. Æstopoda . . .	*Dolichosoma, Ophiderpeton.*
c. Microsauria . . .	*Urocordylus, Ceraterpeton.*
d. Labyrinthodontia Vera .	*Archegosaurus, Mastodonsaurus.*

[1] The classification of Vertebrate Animals here followed is, in the main, the one which has been adopted in the latest of the Catalogues of fossil Vertebrates issued by the Trustees of the British Museum.

2. APODA (OPHIOMORPHA) . . *Cæcilia, Siphonops.* No fossil forms.
3. CAUDATA (URODELA) . . *Molge, Megalobatrachus.*
4. ECAUDATA (ANOURA) . . *Rana, Bufo.*

CLASS IV.—REPTILIA (REPTILES).

1. * ANOMODONTIA.
 - *a.* Pariasauria . . *Pariasaurus, Pariotichus.*
 - *b.* Theriodontia . . *Galesaurus, Clepsydrops.*
 - *c.* Dicynodontia . . *Dicynodon, Oudenodon.*
 - *Group* Placodontia . . *Placodus, Cyamodus.*
2. * SAUROPTERYGIA . . *Plesiosaurus, Pliosaurus, Nothosaurus, Lariosaurus.*
3. CHELONIA.
 - *a.* Athecata . . . *Dermatochelys, * Protostega.*
 - *b.* Testudinata or Thecaphora . . . *Testudo, Chelone, Trionyx, Chitra, Emyda.*
4. * ICHTHYOPTERYGIA . . *Ichthyosaurus, Baptanodon.*
5. * PROTEROSAURIA . . *Proterosaurus.*
6. RHYNCHOCEPHALIA.
 - * *a.* Simædosauria . . *Champsosaurus.*
 - *b.* Sphenodontina . . *Sphenodon, * Hyperodapedon.*
 - * *c.* Homæosauria . . *Homæosaurus, Sapheosaurus.*
7. SQUAMATA.
 - *a.* Lacertilia . . . *Lacerta, Varanus.*
 - *b.* Rhiptoglossa . . *Chamæleon.*
 - *c.* * Dolichosauria . . *Dolichosaurus.*
 - *d.* * Pythonomorpha . *Clidastes, Mosasaurus.*
 - *e.* Ophidia . . . *Python, Coluber, Vipera.*
8. * DINOSAURIA.
 - *a.* Ornithopoda . . *Iguanodon, Scelidosaurus.*
 - *b.* Theropoda . . . *Megalosaurus, Zanclodon.*
 - *c.* Sauropoda . . . *Ornithopsis, Diplodocus.*
9. CROCODILIA.
 - *a.* * Aëtosauria . . *Aëtosaurus.*
 - *b.* * Parasuchia . . *Parasuchus, Stagonolepis.*
 - *c.* Eusuchia . . . *Crocodilus, * Steneosaurus.*
10. * ORNITHOSAURIA.
 - *a.* Pterosauria . . . *Pterodactylus, Rhamphorhynchus.*
 - *b.* Pteranodontia . . *Pteranodon.*

CLASS V.—AVES (BIRDS).

1. * SAURURÆ . . . *Archæopteryx.*
2. RATITÆ.
 - *a.* * Odontolcæ . . . *Hesperornis.*
 - *b.* * Æpyornithes . . *Æpyornis.*
 - *c.* Apteryges . . . *Apteryx, * Megapteryx.*
 - *d.* * Immanes . . . *Dinornis, Palapteryx.*
 - *e.* Megistanes . . . *Casuarius, Dromæus.*
 - *f.* Rheæ *Rhea.*
 - *g.* Struthiones . . . *Struthio.*
 - *h.* Gastornithes . . *Gastornis.*
3. CARINATÆ.
 - *a.* * Odontotormæ . . *Ichthyornis.*
 - *b.* Crypturi . . . *Tinamus.* No fossil forms.
 - *c.* Impennes . . . *Aptenodytes, * Palæudyptes.*
 - *d.* Tubinares . . . *Procellaria, Puffinus.*
 - *e.* Pygopodes . . . *Alca, Colymbus.*
 - *f.* Gaviæ *Larus.*

g. Limicolæ . . . *Limicola, Scolopax.*
h. Alectorides . . . *Grus, Otis.*
i. Fulicariæ . . . *Rallus, Notornis.*
j. Gallinæ . . . *Gallus, Crax.*
k. Columbæ . . . *Columba, Pterocles, * Didus.*
l. Anseres . . . *Anser, Anas.*
m. Palamedeæ . . . *Chauna.* No fossil forms.
n. Odontoglossi . . *Phœnicopterus, * Elornis.*
o. Herodiones . . . *Ciconia, Ardea.*
p. Steganopodes . . *Phalacrocorax, Diomedea.*
q. Accipitres . . . *Aquila, Vultur.*
r. Striges *Otus, Nyctea.*
s. Psittaci *Psittacus, Cacatua.*
t. Picariæ *Picus, Cuculus.*
u. Passeres . . . *Passer, Corvus.*

CLASS VI.—MAMMALIA (MAMMALS).

Sub-class I.—Prototheria.

1. MONOTREMATA . . . *Ornithorhynchus, Echidna.*

Sub-class II.—Metatheria.

1. MARSUPIALIA.
 a. Polyprotodontia . . *Dasyurus, Perameles.*
 b. Diprotodontia . . *Macropus, Phascolemys.*

Sub-class III.—Eutheria.

1. EDENTATA *Cholœpus, Manis, Dasypus.*
2. CETACEA.
 a. Odontoceti . . . *Delphinus, Physeter.*
 b. * Archæoceti . . . *Zeuglodon.*
 c. Mystacoceti . . . *Balæna, Balænoptera.*
3. SIRENIA *Halicore, Manatus.*
4. UNGULATA.
 a. Artiodactyla . . . *Sus, Cervus, Bos.*
 b. Perissodactyla . . *Rhinoceros, Tapirus, Equus.*
 c. * Toxodontia . . . *Toxodon, Typotherium.*
 d. * Condylarthra . . *Periptychus, Phenacodus.*
 e. Hyracoidea . . . *Hyrax.* No fossil forms.
 f. * Amblypoda . . . *Coryphodon, Dinoceras.*
 g. Proboscidea . . . *Elephas, * Dinotherium.*
 Group * Tillodontia . . *Tillotherium.*
5. RODENTIA.
 a. Duplicidentata . . *Lepus, Lagomys.*
 b. Simplicidentata . . *Mus, Sciurus, Hystrix.*
6. CARNIVORA.
 a. Pinnipedia . . . *Phoca, Otaria.*
 b. Carnivora Vera . . *Felis, Ursus, Mustela.*
 c. * Creodonta . . . *Hyænodon, Pterodon.*
7. INSECTIVORA.
 a. Insectivora Vera . . *Talpa, Erinaceus.*
 b. Dermoptera . . . *Galeopithecus.* No fossil forms.
8. CHIROPTERA.
 a. Microchiroptera . . *Vespertilio, Rhinolophus.*
 b. Megachiroptera . . *Pteropus.* No fossil forms.
9. PRIMATES.
 a. Lemuroidea . . . *Lemur, Indris.*
 b. Anthropoidea . . *Macacus, Simia.*

CHAPTER VII.

THE EVOLUTION OF ORGANIC TYPES IN TIME.

The naturalists of last century, and of the earlier part of this century, generally believed that the existing forms of animals and plants had been simultaneously produced by a special act of creation, and that they had not been preceded by pre-existent animals and plants. The occurrence of fossils in the crust of the earth had, it is true, been for long recognised, and had given rise to much learned controversy. By some, fossils were looked upon as having been produced by inorganic agencies, and thus as not being really the remains of animals and plants. Others, again, clearly recognised that fossils were truly the remains of organisms, but regarded them as having belonged to animals that had been destroyed in the Noachian deluge.

At the present day it is universally recognised that our existing animals and plants have been preceded by many antecedent faunæ and floræ. It is also generally admitted that the existing animals and plants are the modified descendants of older forms of life. The actual *beginnings* of life upon the earth are still unknown to us, and are likely ever to remain so. We have no reason to think that the most ancient of known fossils belong to the animals which first came into existence, but much reason to come to an opposite conclusion. Palæontology teaches us that new forms of life have been from time to time introduced upon the earth, and that forms already in existence have become extinct. The laws which have governed this introduction of new and disappearance of old life-forms are still imperfectly known to us, but of the *fact* of this succession of organic types in time no doubt whatever is possible. It is also quite certain that there has been not only a *succession* but likewise a *progression* of organic forms in proceeding from the most ancient of geological periods to the present day. The whole subject of the evolution of life-forms in time involves some of the most profound problems of Palæontology, and can be but very briefly glanced at here. The more im-

portant points in connection with this subject may, however, be shortly considered under the following heads :—

1. *The Primordial Types of Life.*—As above remarked, we know nothing, and are never likely to know anything, of the animals and plants which really constituted the first living beings. Of the life of the Archæan period we at present have no certain knowledge ; but we find representatives of all the Invertebrate sub-kingdoms in the earliest fossiliferous deposits (Cambrian and Ordovician), while Vertebrates appear low down in the Silurian (in the Clinton formation of North America). It may, however, be taken as certain that these ancient fossils cannot possibly be the remains of the really primordial forms of life. Thus, regarded as individuals, these old organic types are as complex and as highly specialised in their structure as are the animals now in existence. Moreover, the great Invertebrate groups of the *Annulosa* and *Mollusca* are found in the Cambrian period to be represented by many diverse forms, and to have already reached a stage of advanced development. It would, however, be at variance with all that we learn from the study of existing organisms, that these great morphological types should, to begin with, have presented themselves under highly specialised forms. Rather must we conclude that a very long period must have been required for the evolution of these varied morphological types, and that the Cambrian fauna was really preceded by many antecedent faunæ which are at present unknown to us.

2. *The Introduction of New Species.*—From the beginning of the Cambrian period onwards, new species of animals have been introduced upon the earth, apparently almost continuously. We may certainly say that the introduction of new species has been "continuous," if we use this term in the sense "of the continued operation of the cause or causes which introduced life at first" (Dawson). It has long been recognised that at certain periods in geological history large numbers of new species were introduced, and this was formerly explained on the supposition that life was periodically destroyed by physical convulsions, and that each of these "catastrophes" was followed by a creation of new animals and plants. The apparent periodicity in the introduction of new species is, however, probably really due simply to the imperfection of the geological record. In all those cases, therefore, where we meet with the apparently sudden incoming of a large number of new life-forms, we may take it for granted that we have to deal with a hiatus in the geological record in the particular area in which this phenomenon is observed. The new forms have, namely, been in existence elsewhere, and what we are observing is not their first introduction upon the earth, but merely their first introduction into the area in question. As regards the period in which we are now living, any apparent ces-

sation in the introduction of new species is probably mainly due to the shortness of the period during which accurate observations have been carried on. Moreover, though our present species have existed for a time which, relatively to man, is very long, this time, estimated geologically, may be, and probably is, very short. It is, further, exceedingly probable that the introduction of new species would, under any circumstances, be imperceptible to a single observer, or even to many successive generations of observers, since the changes by which species are evolved from pre-existing species are probably so slowly produced as to be imperceptible except when fully completed.

3. *Abrupt Appearance of New Species.*—In a large number of instances new morphological types appear to have come into existence abruptly, no closely allied types being known to have preceded them. This is necessarily the case with the animals of the most ancient of the fossiliferous formations (viz., the Lower Cambrian); but a similar phenomenon is observable in hosts of other instances, where we might reasonably expect to find that the new types were preceded by older relatives. It is obvious, however, that this apparently abrupt appearance of a new morphological type—as, for example, the sudden appearance of the great family of the *Rudistæ* in the Cretaceous period—arises from an imperfection in our knowledge. On any theory of evolution, each morphological type must have come into existence, coincidently, both in space and time, with a pre-existing allied morphological type (Wallace). When, therefore, we find new morphological types suddenly appearing on a given geological horizon, in an area where no allied forms have been found in older deposits, we must come to one or other of two conclusions. Either the apparent absence of allied types in older strata is due to the fact that these strata have not been sufficiently investigated, or the apparently sudden introduction of the new forms is due to the fact that the case is not one of their first coming into existence at all, but simply one of their first appearance in the area under observation. In many instances where new organic types suddenly appear in an area, the older deposits in which we might expect to find the remains of the predecessors of these, are missing altogether in the same area. Thus, we cannot expect to find the immediate predecessors of the numerous new life-forms which in Europe usher in the commencement of the Secondary period, till we find the deposits which were laid down in the interval between the close of the Permian and the beginning of the Triassic period. In many other instances, however, where the series of the stratified deposits may be moderately complete, the apparent abruptness of appearance of a given morphological type is really due to the fact that the series has been imperfectly examined; and further investigation would either show that the type in question really began to exist at an earlier period, or

would bring to light allied types from which we might suppose it to have descended.

4. *Relative Persistence of Species in Time.*—The duration in time, or "vertical range" of species, varies greatly in different cases. Some species have an extraordinarily extended range, sometimes passing through two or three geological systems, and in such cases they generally exhibit numerous varieties. This is the case, for example, with some of the Brachiopods, such as *Strophomena rhomboidalis* and *Atrypa reticularis*. Others, again, are singularly restricted in their range, and do not pass beyond the limits of a single subdivision of a system, or, it may be, even of a single band or zone. No case is known in which a species which has once fairly died out has re-appeared at a later period, but there is no absolute impossibility in the separate evolution of the same specific type at two separate periods. As a general rule, it is the animals which have the lowest and simplest organisation that have the longest range in time, and the additional possession of microscopic or minute dimensions seems also to favour longevity. Some of the *Foraminifera*, for example (*e.g.*, *Saccammina Carteri*), seem to have survived, with little or no perceptible alteration, from the Ordovician period to the present day. On the other hand, large and highly organised animals, though long-lived as *individuals*, rarely seem to live long as *species*, and have, therefore, usually a restricted vertical range. Some *genera*, as some species, are short-lived; whereas others extend through a succession of geological periods with extraordinarily little modification. Among these "persistent types" may be specially mentioned the genus *Lingula* among the Brachiopods, and *Nautilus* (in the wide sense of the name) among the Cephalopods, of which the former commenced in the Cambrian and the latter in the Ordovician, and both of which are represented by living species.

5. *Relative Range of Morphological Types in Space.*—The range of particular morphological types in space is as variable as it is in time. Some forms appear to be wholly restricted to some particular area, or, possibly, to a single locality; while others have an enormous range, and are found at very widely distant points of the earth's surface. In a general way, the types which have a wide range in *time* have also a wide range in space. Thus, species of Brachiopods like *Strophomena rhomboidalis* and *Atrypa reticularis*, which range through more than one geological system, have likewise a very extended geographical distribution. Still, a species which is confined to a single system may have an enormous range in space—as, for example, the common *Producta semireticulata* of the Lower Carboniferous; while in some cases types which are restricted to a single "zone," like certain Graptolites and Ammonites, are found to range over very wide areas. The apparently simultaneous appear-

ance of *groups* of morphological types in corresponding geological periods in widely separated areas of the earth's surface is probably fallacious. Such groups must have appeared first in one area, and their extension therefrom must have been the result of subsequent migration. The only other explanation of this phenomenon would be that the same morphological types had been *simultaneously* produced at several widely remote points; but this hypothesis is apparently irreconcilable with any theory of evolution.

6. *Extinction of Morphological Types.*—While new species have been constantly appearing throughout geological time, old species have as constantly been undergoing extinction. In some cases, extinction seems to have taken place with extraordinary abruptness, as seen, for example, in the sudden disappearance of the *Rudistæ* at the close of the Cretaceous period. In other cases, extinction has been a gradual process. In either case, we are to a large extent ignorant of the causes of extinction, and of the laws under which the process is carried on. As a general rule, it may be taken for granted that the sudden disappearance of a whole group of morphological types is more apparent than real. When we have a sufficiently complete series of deposits, it is usual to find that a group has begun to dwindle down long before it finally disappears from the scene. Thus, the Graptolites, the Trilobites, and the Orthoceratites exhibit a progressive diminution as regards the number of specific types before we reach the point at which extinction takes place. *Why* these, and other similar groups, should show such an extraordinary power of rapid extension and of the development of new specific or generic types when first introduced upon the earth, and should thereafter progressively decay and ultimately become extinct, is a problem for which the solution has yet to be found. In any case, it is to be remembered that in many cases "extinction" implies nothing more than continued existence under a new form. That is to say, a species often becomes apparently extinct by becoming gradually modified into a new species, in which case the parent-form actually disappears, but the modified form represents it in later deposits.

7. *Evolution of Morphological Types from pre-existing Forms.*—Palæontology has furnished a mass of evidence in favour of the view that the introduction of new species in past time has been by evolution from pre-existing forms. Taken as a whole, therefore, the evidence of Palæontology points to the operation of some general law of evolution, whereby the later forms of life have been derived from the older ones. The principal palæontological facts which support the general theory of the evolution of organic types from pre-existing forms may be briefly glanced at here under the following heads:—

(*a.*) In the first place, it is a powerful argument in favour of the theory of evolution that the primary morphological types which we recognise among existing animals are identical with the types upon which fossil animals are constructed. While the great majority of fossils are extinct, and while many of them are extremely unlike any existing forms, no fossil animal has hitherto been detected which cannot be referred to one or other of the existing *sub-kingdoms*. Few fossil animals, indeed, possess peculiarities so great as to entitle them to be placed in any *class*, other than in one of the classes of recent forms. On the other hand, the differences between some of the ancient types of life and the existing ones are so great, that palæontologists have been compelled to construct new *sub-classes*, *orders*, and *genera* for their reception.

(*b.*) Again, the investigation of fossil animals has tended to greatly diminish the intervals by which allied groups of existing animals are separated. Many fossil animals, namely, are what has been termed "comprehensive" in their morphological characters. That is to say, they combine in themselves structural peculiarities which in later formations or at the present day are only found separately, in groups more or less widely removed from one another. These "synthetic types" or "collective types" serve to bridge over the gaps between related morphological types, and are thus of special interest from a theoretical point of view. Thus, to take a single example only, the two great classes of the *Sauropsida*—viz., the Reptiles and the Birds—are at the present day separated by a wide interval. Palæontology, however, has brought to light a number of transitional fossil forms—some referable to Birds and some to Reptiles—which more or less markedly combine in themselves the distinctive characters of both groups, and thus partially fill up the gap which now exists between these two great divisions of Vertebrates.

(*c.*) Again, many fossil animals exhibit what are termed "generalised" characters. If, namely, we construct for ourselves a "general" or "ideal" *type* for any great group of animals—a type which shall possess all the essential characters of the group, without its non-essential ones—then we find that the fossil animals of the same group are generally nearer to this type than are its living representatives. Moreover, the older representatives of any given group are usually nearer to the ideal type of the group—or are more "generalised"—than are the later representatives of the same group. All zoologists, however, admit that the process of development in any individual animal is one in which there is a gradual progress from the general to the special, the embryo being nearer to the general type of the group to which it belongs than the adult is. In other words, the embryo animal is more *generalised* than the adult, and the process of development is one of *specialisation*. Admitting this,

it follows that the fossil forms belonging to any given group, in so far as they are "generalised" in their characters, may fairly be said to be "embryonic" types; and as the oldest forms of any given group are usually the least specialised, so they are likewise the most "embryonic." It must be borne in mind, however, that if we speak of fossil animals as being "embryonic types," we can only do so on the distinct understanding that it is not thereby implied that they were in any way degraded forms, or that they were at all less perfectly constructed, or less thoroughly adapted for their surroundings, than their modern representatives.

(*d.*) Lastly, overwhelming evidence in favour of a general theory of evolution is afforded by the similarity of the types of life in successive faunæ and floræ. The animals and plants of each geological system are more closely related to the animals and plants of the system immediately below and to those of the system immediately above, than they are to the organisms of any other rock-group in the stratified series. This fundamental palæontological fact does not admit of reasonable explanation except upon the view that the organisms of each geological period are the modified descendants of those of the preceding period, and are the progenitors of the organisms of the next succeeding period. Each geological system has, of course, more or fewer special types of life, which are confined to it, and which, apparently from inability to adapt themselves to changes in their environment, die out before the close of the system without leaving descendants. Others undergo but slight modification, and appear in the next system as new species, "representative" of the species from which they sprang. Others, again, vary more profoundly, and break up into diverging groups, represented in the succeeding period by more or less widely distinct forms.

8. *General Progression of Organic Types.*—The history of living forms, as preserved in the palæontological record, exhibits a distinct upward progress from the lower to the higher, or from the more generalised to the more specialised. At the present day, the animal kingdom admits of division into a number of primary morphological types, of which some are higher than others. Thus, the Vertebrate type is zoologically higher than any type of the Invertebrates, and the sub-kingdoms of the latter have also a certain relative rank according to the complexity of their plan of organisation. In the same way, within the limits of each sub-kingdom, some of the groups are more "specialised," and therefore higher in the scale, than others.

Not only do the primary morphological types differ from one another in relative zoological rank, as estimated by relative complexity of organic plan, but Palæontology shows clearly that there has been a *progression* in the order of their development, the lower types having, in the main, preceded the higher in time. It is true, as before

pointed out, that it is very doubtful if we are as yet acquainted with the *absolute* time of the first appearance upon the globe of even one of the sub-kingdoms. Future discoveries, therefore, are almost certain to push back still further into the remote vistas of the past the point of time at which each morphological type first made its appearance upon the globe. Nevertheless, there is little likelihood that the *relative* times of appearance of the great groups, as compared with one another, will be affected by any discoveries which we have yet to make. Moreover, as regards the Invertebrate sub-kingdoms, we are, perhaps, never likely to find any reliable evidence which would enable us to fix with precision their relative order of appearance. All of these sub-kingdoms appear in the Cambrian deposits, and the utmost that we can be certain of is that they had been in existence in times long anterior to the Cambrian. Owing, however, to the very general metamorphism which has affected the pre-Cambrian sediments, we cannot hope to ever obtain more than the most scanty evidence, if any, as to the actual origin of the earliest types of life. With regard to the Vertebrate animals, on the other hand, the series of the fossiliferous rocks is long enough to render it certain that within its limits we ought to find traces of the first appearance of, at any rate, the higher classes of these, though we are doubtless likely to remain ignorant of the precise stage in the series at which each first made its appearance. If, therefore, it can be shown that there has been a progression so far as this sub-kingdom is concerned, then there would, by analogy, be the greatest probability that a similar progression has taken place as regards all the sub-kingdoms.

So far as our present knowledge goes, it would appear certain that there *is* such a progression in the Vertebrate sub-kingdom. The classes of Vertebrates make their appearance, on the whole, in the order indicated by their zoological position, the lowest first and the highest last. Where apparent exceptions occur, a reasonable explanation can be given, or our knowledge can be shown to be defective. Thus, the Fishes constitute the lowest group of Vertebrates, and in accordance with this they are the first to make their appearance (in the Silurian period). The Amphibians stand next to the Fishes in zoological rank, and they are the next group of Vertebrates to make their appearance, their earliest known representatives being found towards the close of the Palæozoic period (in the Carboniferous system). A little later than the *Amphibia* (in the Permian period) appear the Reptiles, which constitute the next highest class of Vertebrates. The class of Birds, the next in the series, possesses a palæontological record so fragmentary that we may leave it out of account in this connection ; but the last and highest group of Vertebrates, that of the Mammals, appears for the first time towards the close of the Triassic period. It need only be added, that the gene-

ral progression of zoological types, indicated by the successive introduction of the great classes of Vertebrates in the order of their zoological rank, is amply confirmed and strengthened by what is known as to the geological history of all the great groups of animals of which we have a fairly complete record. Even as regards the Invertebrate sub-kingdoms, where we are admittedly ignorant of the first appearance of the main divisions, we are nevertheless commonly able to show that the minor groups have been successively introduced in the order of their zoological rank. At the same time, it is to be borne in mind that zoological groups do not usually appear for the first time in either their lowest or highest forms. The earliest representatives of each group are, on the other hand, very usually "generalised" types, which have the capacity for either elevation or degeneration in their later development.

9. *The Absence of closely graduated transitional Forms between allied Morphological Types.*—While the general testimony of Palæontology is overwhelmingly in favour of the view that some general law of evolution has operated in the production of the varied forms of life which now exist or have existed in the past, there is no *direct* palæontological evidence which would certainly establish any particular theory as to the precise *modus operandi* of this law. With regard more particularly to the theory of "the origin of species by means of natural selection," which the world owes to the genius of Darwin, the evidence of Palæontology cannot be said to be conclusive. More especially, we have in most cases no sufficient evidence of the former existence of the numerous and closely graduated transitional forms between different species, which must, on this theory, have once existed. It is an essential part of the theory of natural selection that the production of any given species from any pre-existing species can only have been effected through the intervention of a long series of intermediate or transitional forms. It is true that many extinct animals are known which are clearly transitional between existing groups, now more or less widely separated from one another. It is also true that in a certain number of instances (particularly among the Molluscs) it has been found possible to connect two different specific types by means of a long series of intermediate links, the separate members of the series differing only in minute characters. As a general rule, however, the known transitional forms between allied groups are few in number, and are so far isolated from one another and from the forms they connect as to be in themselves absolutely distinct morphological types. It cannot be denied, therefore, that palæontology has, so far, to a large extent, failed to bring forward the numerous and *closely graduated* series of intermediate forms which must at one time have existed, supposing "natural selection" to be the sole agent in the origination of new species. The absence

of a sufficient number of such transitional forms, and the insufficient connection between such as are known to exist, may doubtless be in part explained by the known "imperfection of the geological record"; but this does not appear to offer an adequate solution of the difficulty. The theory of "the origin of species by means of natural selection," as elaborated by the master-mind of Darwin, constitutes, nevertheless, an invaluable, indeed an indispensable, guide in all branches of palæontological research.

LITERATURE.

[With regard to the subjects dealt with in the introductory portion of this work, the following are some of the original sources of information to which the student may have recourse. It is to be remembered, however, in the case of this, as of subsequent bibliographical lists of a similar character, that nothing more has been attempted than to give a selection of the more important original memoirs.]

1. "Anniversary Address to the Geological Society of London." (Minute Structure and Chemical Composition of the Calcareous Skeleton of Invertebrates; Structure of Limestones, &c.) 1879. Sorby.
2. "Anniversary Address to the Geological Society of London." (Geological Contemporaneity and Persistent Types of Life.) 1862. Huxley.
3. "Address to the Geological Section of the British Association for the Advancement of Science." (Homotaxis.) 1884. Blanford.
4. "Relative Ages of American and English Fossil Floras." 'Geological Magazine,' 1884, p. 496. J. Starkie Gardner.
5. "Homotaxis and Contemporaneity." 'Geological Magazine,' 1886, p. 293. Oldham.
6. "The Application of Biology to Geological History." 'Proc. Biological Soc. of Washington,' 1886. C. A. White.
7. "The Inter-relation of Contemporaneous Fossil Faunas and Floras." 'Amer. Journ. Sci. and Arts,' vol. xxxiii., p. 364, 1887. C. A. White.
8. "The Origin of Species by means of Natural Selection." (Chapters x. and xi., on "the Imperfection of the Geological Record," and on "the Geological Succession of Organic Beings.") Sixth Edition, 1872. Darwin.
9. "Défense des Colonies." 1865 and 1870. Barrande.
10. "The Pre-Devonian Rocks of Bohemia." (The "Colonies" of Barrande.) 'Quart. Journ. Geol. Soc.,' vol. xxxvi., 1880. J. E. Marr.
11. "On the Nomenclature, Origin, and Distribution of Deep-sea Deposits." 'Proc. Roy. Soc. Edin.,' 1884. John Murray and A. Renard.
12. "Report on the Deep-sea Deposits." 'Narrative of the Cruise of H.M.S. Challenger,' vol. ii., Part ii., 1885.
13. "The Geographical and Geological Distribution of Animals." 1887. Heilprin.
14. "Ueber klimatische Zonen während der Jura- und Kreide-Zeit.' 'Denkschriften der kais. Akad. der Wiss.' Vienna. 1883. Neumayr.
15. "Les Ancêtres de nos Animaux dans les Temps Géologiques." 1888. Gaudry.

PART II.

PALÆOZOOLOGY

INVERTEBRATA

BY

H. ALLEYNE NICHOLSON

PART II.

CHAPTER VIII.

SUB-KINGDOM I.—PROTOZOA.

THE sub-kingdom *Protozoa*, as the name implies, includes the most lowly organised members of the animal kingdom, and may be defined as comprising *animals composed of undifferentiated protoplasm, or, at most, of protoplasm so far differentiated as to have developed an outer "wall" and a central "nucleus," the organism in the latter case becoming a "cell." In no case are definite "tissues" developed by the differentiation of a primitive cellular aggregate. There is no proper "body-cavity"; no nervous system; and either no alimentary apparatus, or one of a rudimentary nature.*

The *Protozoa* are small, commonly microscopic animals, for the most part aquatic in their habits. The contractile, jelly-like protoplasm, or "sarcode," of which the body is composed may be entirely naked, or may have the power of secreting hard structures, of horn, lime, or flint. The following table exhibits the chief groups of the *Protozoa*.

CLASS I. GREGARINIDÆ.—Protozoa in which the body has the form of a simple cell, without any mouth-aperture, and destitute of the power of emitting "pseudopodia." The Gregarines are for the most part internal parasites, and possess no hard structures.

CLASS II.—RHIZOPODA (SARCODINA).—Protozoa which are destitute of a mouth, and have the power of emitting extensile and contractile processes of protoplasm ("pseudopodia"). The sarcode may or may not have the power of secreting hard structures.

Order 1. *Monera.—Ex.* Protamœba.
Order 2. *Amœbea.—Ex.* Amœba.
Order 3. *Foraminifera.—Ex.* Globigerina.
Order 4. *Radiolaria.—Ex.* Haliomma.
Order 5. *Heliozoa.—Ex.* Actinophrys.

CLASS III.—INFUSORIA (Infusorian Animalcules).—Protozoa which are typically provided with a mouth and rudimentary digestive cavity, which do not possess the power of emitting pseudopodia, but which are furnished with vibratile cilia or with contractile filaments. They are mostly microscopic in size, and are mostly destitute of the power of secreting hard skeletal structures.

Regarded palæontologically, we may eliminate from the *Protozoa* the entire class of the *Gregarinidæ*, with the Rhizopodous orders of the *Monera*[1] and *Amœbea*, no trace of the past existence of which has yet been obtained, or, from their soft-bodied nature, is ever likely to be. For all practical purposes the same may be said of the large and universally distributed class of the Infusorian Animalcules.[2] Some of these, however, possess chitinous or membranous cases, which might possibly be preserved in a fossil state; and Ehrenberg has found in the flints of the Chalk certain microscopic bodies, which he regarded as being the protective carapaces of *Peridinium* and allied forms of Flagellate Infusoria. With this doubtful exception, however, no Infusorian animalcule has ever been detected in the fossil state, though the class has doubtless existed from the most remote antiquity. There remain, then, only the three Rhizopodous orders of the *Foraminifera*, *Radiolaria*, and *Heliozoa*, in all of which the soft protoplasmic body is generally strengthened by hard structures of horn, lime, or flint. The last mentioned of these orders comprises fresh-water organisms, in which a skeleton is absent or imperfectly developed, and no traces of fossil *Heliozoa* have hitherto been met with. On the other hand, the *Foraminifera* and *Radiolaria* usually have a well-developed skeleton, and are more or less extensively represented as fossils, so that they demand attention separately and in detail.

FORAMINIFERA.

The *Foraminifera* may be defined as *Rhizopoda in which the body is protected by a shell or "test," which is composed of carbonate of lime, or which may consist of particles of sand cemented together by some animal cement, or may be simply horny (chitinous). The body-substance gives out long and thread-like processes (pseudopodia), which interlace with one another to form a network, and often coalesce at their bases to form a continuous layer of sarcode outside the shell. The pseudopodia* (fig. 18) *reach the exterior either by perforations in*

[1] The "coccoliths" are sometimes regarded as being referable to the *Monera*; but they will be considered here as belonging to the vegetable kingdom, and they will be briefly described in speaking of fossil *Algæ*.

[2] "Fossil Infusoria" are often spoken of as forming more or less extensive deposits in the earth's crust, but the organisms so named are really *Diatoms* and *Polycystina*.

the walls of the shell, or simply by the mouth of the latter, or by both these sets of apertures combined.

From a palæontological point of view the only part of a Foraminifer with which we have to deal is the shell or "test," and there are several points to notice in this connection. Firstly, as regards the actual composition of the shell, it is in the majority of cases calcareous, or composed of carbonate of lime, but it is rarely chitinous, and it is not uncommonly "arenaceous"—that is, composed of

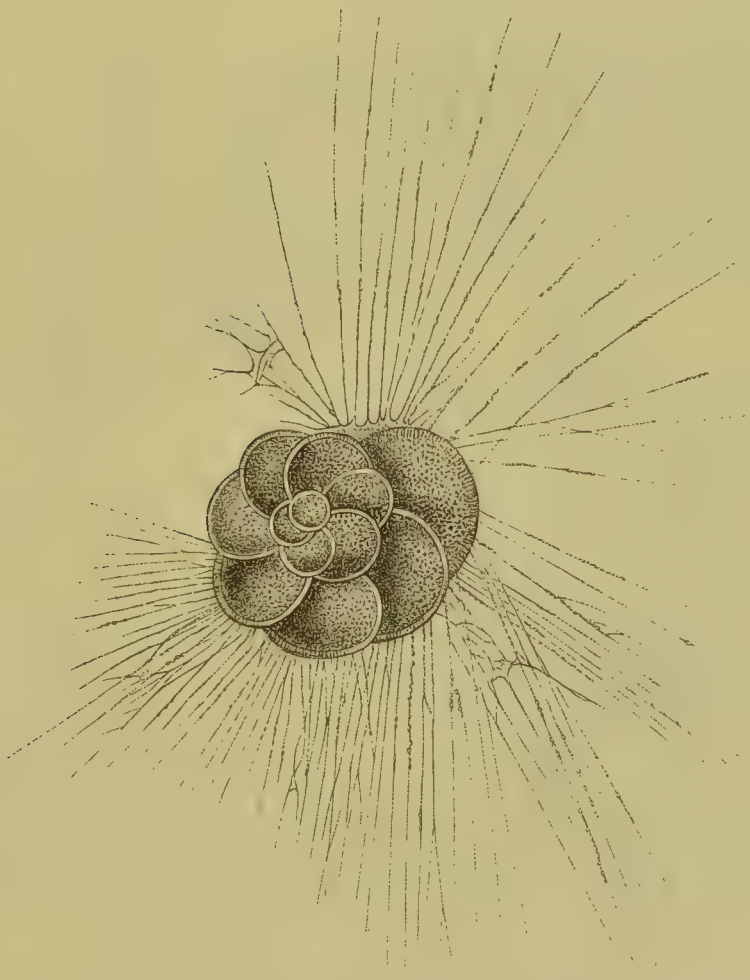


Fig. 18.—A many-chambered Foraminifer (*Rotalia veneta*) with the radiating and netted pseudopodia protruded. Greatly magnified. (After Max Schultze.)

particles of sand cemented together by some animal substance or by carbonate of lime. With the horny or chitinous *Foraminifera* (*Gromidæ*) we have nothing to do here, as they have never been, and are never likely to be, detected in a fossil condition.

An advance upon the chitinous shell is that presented by the so-called "arenaceous" *Foraminifera* (fig. 19), which are among the largest of the living types, the test being sometimes half an inch or more in length. In some cases the "arenaceous" test is nothing more than a chitinous envelope, protected by a layer of mud, or having sand-grains more or less largely embedded in its substance (H. B. Brady). Typically, however, the test of the arenaceous *Foraminifera* consists of sand-grains or other foreign particles united

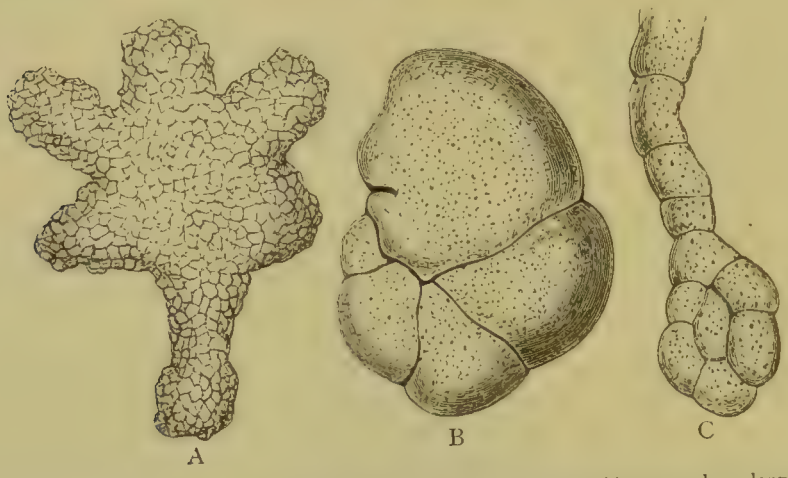


Fig. 19.—Shells of Arenaceous Foraminifera. A, Test of *Astrorhiza*, greatly enlarged; B, Test of *Trochammina ringens*, enlarged thirty times; C, Test of *Trochammina lituiformis*, enlarged eighteen times. (After W. B. Carpenter and Brady.)

together by a variable amount of cementing material, this latter containing from two to three per cent of carbonate of lime together with a notable proportion of peroxide of iron. The arenaceous *Foraminifera* have, as a rule, no pseudopodial apertures or "foramina" in the walls of the test, the pseudopodia being emitted from a single general or "oral" aperture, or from a number of apertures in the wall of the last chamber. Though normally "imperforate," there are, however, certain forms of the arenaceous or sub-arenaceous *Foraminifera* (such as *Valvulina*, *Nodosinella*, and *Endothyra*) in which the walls are pierced by pseudopodial foramina. Indeed, some degree of porosity appears to be commonly present, and in some forms there is no "oral aperture" to the test at all.

The great majority of the *Foraminifera* possess a shell composed essentially of carbonate of lime, with or without variable quantities of other constituents. Two chief varieties of these calcareous tests are known, termed respectively the "porcellanous" and the "hyaline" or "vitreous" types. In the so-called "porcellanous" types, the test is quite homogeneous in its composition, opaque-white when seen by reflected light, and destitute of pores or foramina

for the emission of pseudopodial filaments. In all the porcellanous *Foraminifera*, therefore, the shell is "*imperforate*," and the pseudopodia are emitted from a general "oral aperture." There is also reason to believe that the shell in these types is largely composed of aragonite. Though normally calcareous, the test may be encrusted by sand-grains, or it may be composed of siliceous particles embedded in a chitinous envelope, or, as shown by Dr H. B. Brady to sometimes occur in examples of *Miliola* dredged from great depths, it may even be genuinely siliceous. On the other hand, in the so-called "hyaline" or "vitreous" types of the *Foraminifera*, the calcareous test (composed principally of calcite) is glassy and transparent, and its walls are perforated by numerous minute tubes through which the pseudopodia are emitted. In the series of the hyaline *Foraminifera*, therefore, the test is said to be "*perforate*." Hence, in vertical sections of the shell of any such type (*e.g.*, *Globigerina*), the test is seen under the microscope to be traversed by closely set tubules, running at right angles to the outer and inner

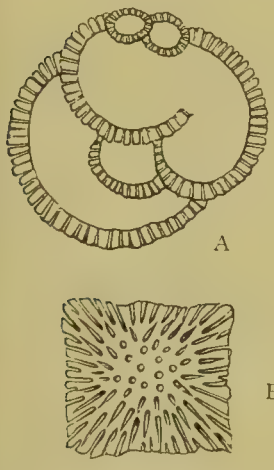


Fig. 20.—A, Vertical section of the test of *Globigerina bulloides*, highly magnified, showing the pseudopodial tubes; B, Tangential section of the same, showing the tubules in transverse section. (Original.)

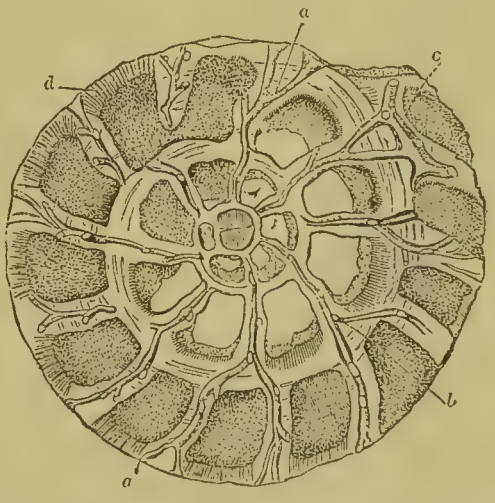


Fig. 21.—Section of the shell of *Rotalia Schroteriana*, magnified, showing pseudopodial tubes in the walls (*d*). The test is also traversed by a series of radiating and transverse canals (*a*, *b*, *c*). (After Williamson and Carpenter.)

surfaces of the shell; while in tangential sections (*i.e.*, sections parallel with the surface) these tubules are transversely divided, and appear as dark spots or clear pores (see figs. 20 and 21).

The presence, or absence, of pseudopodial tubes in the walls of the test has been employed as a character whereby the entire group of the *Foraminifera* might be divided into the two sections of the *Perforata* and *Imperforata*; the former including the hyaline or

vitreous types, while in the latter are comprised the "porcellanous," "arenaceous," and "chitinous" types. It has been shown, however, that this division is not strictly natural, since various arenaceous types possess a test which is more or less extensively porous. It would appear, in fact, that the composition of the shell is liable to variation, in accordance with the nature of the material obtainable by the organism at any particular station, and that it is therefore possible to attach too great value to this character in framing a classification of the *Foraminifera*.

Again, as regards the *form* of the shell, great differences exist among the *Foraminifera*, and as concerns the mere external configuration, this is so variable that little or no value can be attached to it in classification. Moreover, in the two great series of the Perforate and the Imperforate *Foraminifera* it is common to find parallel or "isomorphic" groups. That is to say, we meet with two series of forms, repeating each other's peculiarities and variations in *form*, but the shell in the one series being perforate, while in the other it is imperforate.

The simplest form among the *Foraminifera* is that of a single spheroid of sarcode, capable of secreting for itself a hard covering, as in the flask-shaped *Lagena* (fig. 29, *f*) or the globular *Orbulina* (fig. 22). Forms such as these are said to be "unilocular" or "monothalamous," the test consisting of but a single chamber, not subdivided by partitions or "septa." In the more complex *Foraminifera*, the sarcode of the body undergoes a subdivision into partially separated segments, produced by constrictions in the growing protoplasm, and each of these segments becomes more or less completely divided off from its neighbours, or enclosed by a wall of shell. In these "multilocular" or "polythalamous" *Foraminifera*, therefore, the shell ultimately comes to consist of a series of chambers, separated by partitions of the test, and filled with sarcode. The partitions, or "septa," between the different chambers, are, however, perforated by one or more apertures, through which pass connecting bands, or "stolons," of sarcode; so that the sarcode occupying the different chambers is united into a continuous and organic whole. Each segment may give out its own pseudopodia through perforations in its investing wall (fig. 18), or the pseudopodia may be simply emitted from the mouth of the shell by the last segment only. In any case, the direction in which the segments are developed is governed by a determinate law, and differs in different species, the form ultimately assumed by the shell depending wholly upon this. The forms assumed by the shells of *Foraminifera* are,

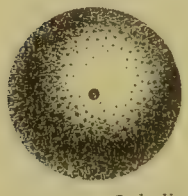


Fig. 22.—*Orbulina universa*. A simple Foraminifer from the Pliocene strata (Sub-Apennine beds) of Italy. (D'Orbigny).

however, extremely variable, even within the limits of a single species, and it would be impossible to notice even the chief types in this place. There are, however, two or three important variations which may be mentioned. If the buds are thrown out from the primitive spherule in a linear series so as to form a shell composed of numerous chambers arranged in a straight line, we get such a type as *Nodosaria* (fig. 29, *g*). When the new chambers are added in a spiral direction, each being a little larger than the one which preceded it, and the coils of the spiral lying in the same plane, we get such a form as *Cristellaria* (fig. 23). These are the so-called "nautiloid" *Foraminifera*, named from the resemblance of the shell, in figure, to that of the Pearly Nautilus. From this resemblance the nautiloid *Foraminifera* were originally placed in the same class as the *Ammonites* (*Cephalopoda*), but their true position was shown by the examination of their soft parts. In the typical nautiloid shell the convolutions of the spiral all lie in one plane; but in other cases, as in *Rotalia* or *Pulvinulina* (fig. 24), the shell becomes turreted or top-shaped, in consequence of the coils of the spiral passing obliquely round a



Fig. 23.—*Cristellaria echinata*, a "nautiloid" Foraminifer. (D'Orbigny.)

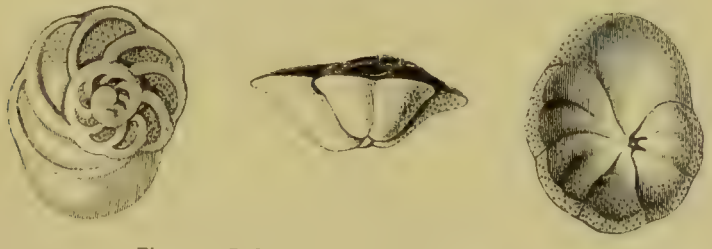


Fig. 24.—*Pulvinulina Boueana*. (D'Orbigny.)

central axis. In other cases, as in *Tinoporus*, the chambers are arranged in an irregular or "acervuline" manner.

In the majority of the polythalamous *Foraminifera*, the successive chambers of the test are so produced that the septum between any two of them is formed solely by the anterior wall of the older chamber, which thus constitutes the posterior wall of the newer one (fig. 25). In the highest types of the compound *Foraminifera*, however, each chamber is provided with its own proper wall of shell, each segment, as it is produced, forming for itself a posterior wall which applies itself to the anterior wall of the preceding segment; so that each septum ("septal plane") is composed of *two* lamellæ, as seen

in fig. 26, A (Carpenter). Moreover, "in the higher types of the hyaline or vitreous series we frequently meet with an 'intermediate' or 'supplemental' skeleton, formed by a secondary or exogenous deposit upon the outer walls of the chambers, by which they receive a great accession of strength. This deposit not only fills up what would otherwise be superficial hollows at the junctions of the chambers (fig. 26, A *d*), or (as in *Polystomella*) at the umbilical depression, but often forms a layer of considerable thickness over the whole surface, thus separating each whorl from that which encloses it; and it is sometimes prolonged into outgrowths that give a very peculiar variety to the ordinary contour, as in some varieties of *Rotalia* and *Polystomella*, but most characteristically in *Calcarina* (fig. 26, B), and the stellate form of *Tinoporus*. This intermediate or supplemental skeleton, wherever developed to any considerable extent, is traversed by a set of 'canals,' which are usually arranged upon a systematic plan, and are sometimes distributed with considerable minuteness" (Carpenter). The canals of this system are doubtless filled in the living state by prolongations of the sarcode, which serve to keep up the vitality of the intermediate skeleton. This intermediate skeleton, with its canal-system, is largely developed in many of the highest and largest of the types of the hyaline *Foraminifera*, and very specially so in the "Nummulites" and their immediate allies.



Fig. 25.—Section of the shell of *Nodosaria rapa*, showing the mode of formation of the successive chambers. *o* Oral aperture of the test; *w* Wall; *i* Primordial chamber.

As regards the distribution of the *Foraminifera* in *space*, a few forms (all belonging to the single family of the *Gromidæ*) are fresh-water in habit, but the vast majority are inhabitants of the sea.

As regards the marine forms, very many species live in comparatively shallow water, but certain forms are found at great depths in the ocean. A small number of forms, belonging, according to Dr Henry B. Brady, to eight or nine genera, are pelagic in their habits, and "pass their existence, either in part or entirely, at the surface of the ocean or in mid-water." Though only a few genera have pelagic representatives, these few are of great importance, owing to the extraordinary profusion in which they occur individually. The principal pelagic genus is *Globigerina*, most of the species of which live in the open sea, though one species of the genus seems to always live at the bottom. The shells of the pelagic *Foraminifera*, after the death of the animal, fall to the bottom of the sea, where they accumulate to form (along with the shells of the species which live habitually at the bottom) great deposits of "Foraminiferal mud."

The most important deposit of this nature at the present day is the well-known "Globigerina ooze," which is found to cover vast areas of the sea-bottom in all the great oceans, mostly at depths of from 600 to about 2500 fathoms, and which is of special interest from the resemblances which it presents to the White Chalk. The "Globigerina ooze" is a whitish or greyish mud, principally composed of carbonate of lime, but containing a considerable proportion of silice-

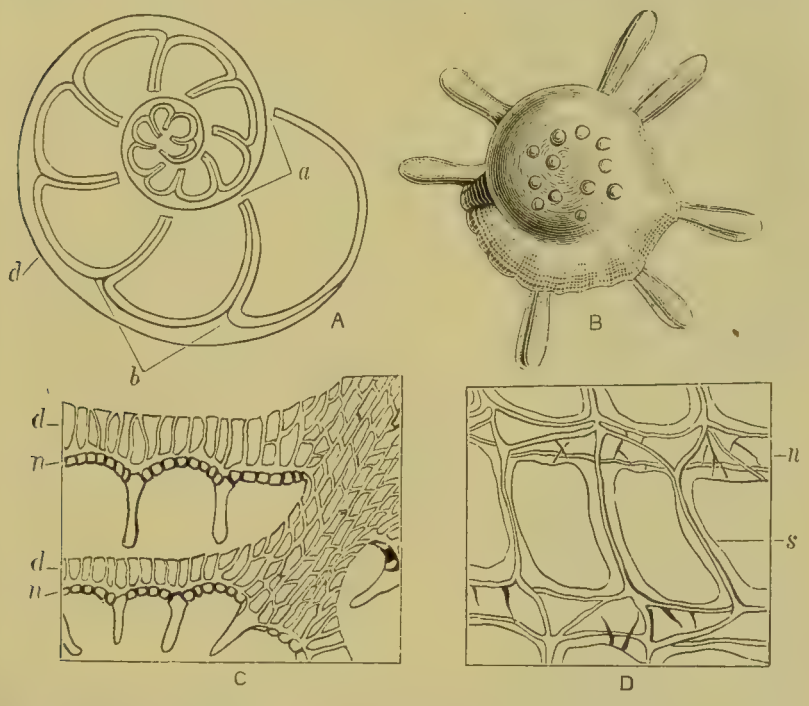


Fig. 26.—A, Diagram of one of the higher forms of the vitreous *Foraminifera*, showing the double nature of the septa (*b*), the stolon-passages between successive chambers (*a*), and the supplemental skeleton (*d*); B, Test of *Calcarina Spengleri*, magnified twelve diameters, showing the spines formed by the supplemental skeleton; C, Part of a section of the test of *Calcarina*, magnified fifty diameters, showing the tubulated "proper walls" of the chambers (*n*), and the canal-system of the intermediate skeleton (*d*); D, Part of the test of *Nummulina lævigata*, highly magnified, showing the canal-system of the septa (*s*), and marginal cord (*n*). (After Carpenter.)

ous matter, along with a variable quantity of subordinate ingredients such as alumina. When examined microscopically, the Globigerina mud (fig. 27) is found to consist principally of the entire or broken shells of *Foraminifera*, belonging mostly to the genera *Globigerina*, *Orbulina*, *Hastigerina*, and *Pulvinulina*, together with many of the singular calcareous organisms known as "coccoliths." In the nature of the organisms of which it is composed, the Globigerina ooze of the present day presents the closest resemblance to White Chalk; while the chemical differences between them—especially as regards the relative percentage of silica—admit, as will be more particularly

pointed out hereafter, of satisfactory explanation. There are, however, other differences between the two, especially as regards the characters of the Molluscan fauna of the latter, which would indicate that the Globigerina ooze and the White Chalk were not formed under conditions precisely alike.



Fig. 27.—Section of hardened Globigerina ooze, enlarged about twelve times. Recent. (Original.)

As regards the distribution of the *Foraminifera* in *time*, representatives of the group are found in almost all, or in all, rock-groups in which limestones are developed from the Ordovician period onward. Leaving the much disputed *Eozoön* on one side, no remains of *Foraminifera* have hitherto been recognised as occurring in any deposit older than the Ordovician. As regards the older rocks, the remains of *Foraminifera* are usually found most abundantly in limestones, or in calcareous shales, and particularly in the shaly partings which separate calcareous bands. In many cases, they have contributed notably to the composition of the solid crust of the earth, and have often built up massive and widely extended limestones. In other cases, where they are present in smaller quantity, they may be commonly detected in thin sections of limestone. In some instances, the tests of *Foraminifera* have been infiltrated, prior to fossilisation, with glauconite (silicate of iron and potash), and the actual shell has subsequently been dissolved away. In some of the warmer seas of the present day, green sands are found to be in course of deposition, the grains of which are largely composed of internal casts in glauconite of the shells of *Foraminifera*; and it is probable that the green grains of various deposits, and especially of the Cretaceous system, are in part of a similar nature.

If we omit the group of the *Receptaculitidæ*, regarded by Hinde as referable to the *Porifera*, the Ordovician, Silurian, and Devonian limestones exhibit in general a remarkable, and, in fact, an unaccountable, absence of the remains of *Foraminifera*; since the variety of the types of these organisms represented in the limestones of the Carboniferous period would justify the conclusion that the order is one of very high antiquity. The remains of *Foraminifera* are not, however, absolutely wanting in these ancient deposits, since the recent genus *Saccammina* has been found to occur in rocks of Ordovician age, while the Devonian limestones occasionally con-

tain the tests of *Foraminifera*. In the Carboniferous period, most of the limestones can be shown by microscopical examination to contain the shells of *Foraminifera* in larger or smaller numbers (see fig. 4); and some of them are so largely composed of the cases of these minute organisms as to become truly "Foraminiferal limestones." Of this nature are the great Fusulina limestones of Russia and North America, and the Saccammina limestone of Britain. It is interesting to notice that the highly specialised genus *Nummulina*, which attained such a vast development in the Tertiary period, is represented for the first time in the Carboniferous limestone. In the Permian limestones *Foraminifera* are tolerably abundant, but on the whole nearly resemble their Carboniferous predecessors.

In the Mesozoic period, the remains of *Foraminifera* are more or less abundant in the Triassic and Jurassic systems, occurring in limestones, shales, or marls, and sometimes being present in sufficient numbers to give rise to regular Foraminiferal limestones. In the Cretaceous period, the most remarkable Foraminiferal rock is the White Chalk itself. This well-known and widely extended formation can be readily shown by microscopical investigation to be very largely made up of the entire or broken shells of *Foraminifera*, amongst which the genus *Globigerina* plays a predominant part (fig. 28). There is thus a close and striking similarity between the White Chalk and the "Globigerina ooze" of modern seas. The principal distinction between Chalk and consolidated Globigerina mud is found in the fact that the latter contains a considerable proportion of siliceous matter, while the former consists of from ninety-five to ninety-eight per cent of carbonate of lime, and is nearly or quite free from disseminated silica. This distinction is, however, more apparent than real, and depends in reality upon the changes which the Chalk has undergone subsequent to its original deposition. The siliceous matter in the modern Globigerina mud is due to the presence of a larger or smaller intermixture of the flinty tests of Radiolarians, the spicules of siliceous Sponges, the tests of Diatoms, and the like. There is no reason to doubt, however, that the Chalk, when first laid down, similarly contained a larger or smaller quantity of siliceous matter in the form of the skeletons of flint-producing organisms such as Sponges. The silica of these

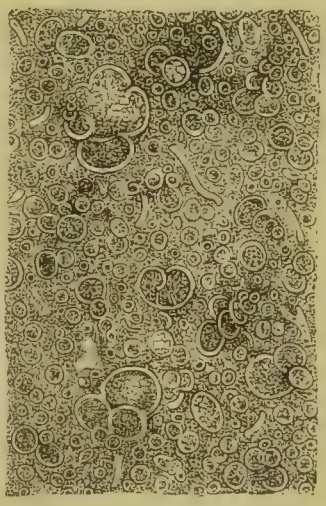


Fig. 28. — Section of White Chalk, from Sussex, enlarged about fifty times. (Original.)

skeletons in course of time underwent solution, and the siliceous Sponges are now found in the White Chalk only in the form of casts, or with their original skeleton replaced by some such substance as peroxide of iron. The dissolved silica thus produced was ultimately segregated from the mass of the Chalk, and is now represented by the nodules of flint which form such a characteristic feature of parts of the White Chalk. It would appear, therefore, that the White Chalk in its original chemical composition must have been very closely similar to the modern Globigerina ooze; and it is a reasonable conclusion from its general purity that it must, like its modern analogue, have been deposited in a deep and open ocean, at a considerable distance from land. At the same time, the characters of the *Mollusca* which are predominant in the Chalk, would go to show that this remarkable Foraminiferal deposit must have been laid down in general at depths less than those at which the modern Globigerina ooze is now accumulated.

In the Tertiary period, lastly, the remains of *Foraminifera* are abundant and varied, and are often present in such numbers as to give rise to more or less extensive Foraminiferal limestones. The most notable of these is the great "Nummulitic limestone" of the Eocene. In the later Tertiary deposits, the genera represented are mostly those now in existence, and many of the species are identical with living forms. The *Foraminifera*, in fact, like other lowly organised forms, have been very "persistent" types of life. A number of the Cretaceous species, indeed, appear to be inseparable from existing forms, while some living species are believed to date from even an earlier period. As regards the *genera*, the prevalent types in Carboniferous times still survive unchanged; and Dr Carpenter has enunciated the conclusion that upon the whole "there is no evidence of any fundamental modification or advance of the Foraminiferous type from the Palæozoic period to the present time."

Classification of the Foraminifera. — The classification of the *Foraminifera* has proved a matter of considerable difficulty. The older arrangements were unnatural, as being based wholly on the form of the shell, a point in which the *Foraminifera* show a most marvellous variability. For this reason, the artificial systems proposed by D'Orbigny and Max Schultze have now been generally abandoned, and their place has been taken by other more natural schemes of classification, and especially by those put forward independently and almost simultaneously by Professor von Reuss upon the Continent, and by Dr W. B. Carpenter, Mr Parker, and Professor T. Rupert Jones in this country. Both these arrangements agree in the essential feature that they divide the *Foraminifera* into two great primary divisions, in accordance with the nature of the shelly investment. In the one division (*Imperforata*), the test is not perforated

by pseudopodial apertures, and it may be either "arenaceous" or "porcellanous." In the other division, the test is perforated by more or less numerous pseudopodial foramina, and to this division the name of *Perforata* is applied. The following tables exhibit the arrangements proposed by Carpenter, Parker, and Rupert Jones, on the one hand, and Reuss, on the other hand; the former being the most natural, and the one most widely adopted :—

A. Classification of the Foraminifera, according to Carpenter, Parker, and Rupert Jones.

Sub-Order I. Imperforata.—Test membranous, calcareous, or arenaceous, not perforated by pseudopodial foramina.

Family 1. *Gromida.* Family 2. *Miliolida.*
Family 3. *Lituolida.*

Sub-Order II. Perforata.—Test perforated by pseudopodial foramina, generally calcareous.

Family 1. *Lagenida.* Family 2. *Globigerinida.*
Family 3. *Nummulinida.*

B. Classification of the Foraminifera according to Reuss.

I. Foraminifera with a Non-perforate Test.

A.—With arenaceous tests.

1. *Lituolidea.* 2. *Uvellidea.*

B.—With compact, porcellanous, calcareous tests.

1. *Squamulinidea.* 3. *Peneroplidea.*
2. *Miliolidea.* 4. *Orbitulitidea.*

II. Foraminifera with a Perforate Test.

A.—With a glassy, finely porous, calcareous test.

1. *Spirillinidea.* 5. *Polymorphinidea.*
2. *Ovulitidea.* 6. *Cryptostegia.*
3. *Rhabdoidea.* 7. *Textilaridea.*
4. *Cristellaridea.* 8. *Cassidulinidea.*

B.—With an exceedingly porous, calcareous test.

1. *Rotalidea.*

C.—With a calcareous shell, traversed by a ramified canal-system.

1. *Polystomellidea.* 2. *Nummulitidea.*

On the other hand, Dr H. B. Brady, one of the highest living authorities on the *Foraminifera*, has recently pointed out that, in the light of our present knowledge, the primary division of the order into the two sections of the *Perforata* and *Imperforata* cannot be

considered to be natural. It is now well known that many of the Arenaceous *Foraminifera*, forming one of the principal groups in the old section of the *Imperforata*, have diffused pseudopodial apertures, with or without a general aperture as well, so that their test is truly "perforate." The retention of the sections *Perforata* and *Imperforata* would therefore necessitate the splitting up of the Arenaceous *Foraminifera* into two series, one with a "perforate" and the other with an "imperforate" test. In view of this fact, Dr Brady has abandoned the minute structure of the test as an exclusive basis for the classification of the *Foraminifera*, and has proposed the following arrangement of the order into families :—

Order Foraminifera (Reticularia).

Family 1. Gromidæ.—Test chitinous; smooth or encrusted with foreign bodies; with a pseudopodial aperture at one or both extremities. *Ex.—Gromia, Microgromia, Lieberkühnia.*

Family 2. Miliolidæ.—Test imperforate; normally calcareous and porcellanous, sometimes encrusted with sand, or, under certain conditions, chitinous or siliceous. *Ex.—Biloculina, Penecroplis, Orbitolites.*

Family 3. Astrorhizidæ.—Test composed of sand-grains or other foreign bodies, usually more or less united into a coherent test by a cementing material. Usually the test is monothalamous, often branched or radiate, sometimes partially subdivided, but seldom or never truly septate. *Ex.—Astrorhiza* (fig. 19, A), *Rhabdammina, Saccammina.*

Family 4. Lituolidæ.—Test arenaceous, usually regular in contour; septation of the polythalamous forms often imperfect; chambers frequently labyrinthic. *Ex.—Lituola, Trochammina* (fig. 19, B and C), *Endothyra.*

Family 5. Textularidæ.—Tests of the larger species arenaceous, with or without a perforate calcareous basis; smaller forms hyaline and perforated. Chambers arranged in two or more alternating series, or spiral, or confused. *Ex.—Textularia, Valvulina.*

Family 6. Chilostomellidæ.—Test calcareous, perforate, polythalamous. Segments following each other from the same end of the long axis, or alternately at the two ends, or in cycles of three; more or less embracing. Aperture a curved slit at the end or margin of the final segment. *Ex.—Chilostomella.*

Family 7. Lagenidæ.—Test calcareous, finely perforated; either monothalamous, or consisting of a number of chambers joined in a straight, curved, spiral, alternating, or (rarely) branched series. Aperture simple or radiate, terminal. No interseptal skeleton nor canal-system. *Ex.—Lagena, Nodosaria, Cristellaria.*

Family 8. Globigerinidæ.—Test free, calcareous, perforate; chambers few, inflated, arranged spirally. Aperture single or multiple, conspicuous. No supplementary skeleton nor canal-system. *Ex.—Globigerina, Orbulina.*

Family 9. Rotalidæ.—Test calcareous, perforate; free or adherent. Typically spiral and "rotaliform"—*i.e.*, coiled in such a manner that the whole of the segments are visible on the upper surface, those of the last convolution only on the inferior or apertural side, sometimes one face being more convex, sometimes the other. Aberrant forms evolute, outspread, acervuline or irregular. Some of the higher modifications with

double chamber-walls, supplemental skeleton, and a system of canals. *Ex.—Rotalia*, *Discorbina*, *Carpenteria*, *Calcarina*, *Tinoporus*.

Family 10. NUMMULINIDÆ.—Test calcareous and finely tubulated; typically free, polythalamous, and symmetrically spiral. Usually a "supplemental skeleton" and canal-system. *Ex.—Nummulina*, *Polystomella*, *Fusulina*, *Nonionina*.

In connection with the general subject of the classification of the *Foraminifera*, the following remarks by Dr Brady may advantageously be quoted; since they not only have a most important bearing upon the special point in question, but forcibly express the principles which should guide the philosophic naturalist in his systematic treatment of all such variable forms of life: "A purely artificial classification is ill adapted to the conditions presented by a class of organisms like the *Foraminifera*, largely made up of groups of which the modifications run in parallel lines. This 'isomorphism,' demonstrated chiefly by the labours of Messrs Parker and Jones, whilst it is the source of most of the difficulties the systematist has to contend with, is, at the same time, the key to the natural history of the order as at present accepted. It exists not merely between a single series, in one of the larger divisions, with a single series in another, but often amongst several series even of the same family. It not unfrequently happens that a member of one group presents a greater similarity to its isomorph in another group, with which it has no relationship, than it does to any other member of its own group. Take a familiar illustration—suppose the fingers of the two hands to represent the modifications ('species') of two such parallel types of *Foraminifera*: the thumb of one hand resembles more closely the thumb of the other hand than it does any other of the fingers on its own. In other words, the extreme member of one series bears greater similarity to its isomorph in the other series than it does to its own nearer relations, and so on through the remaining members of the respective groups. Under conditions like these, artificial subdivision, based upon minor morphological characters, is certain to infringe the order of nature, owing to its tendency in some cases to separate forms closely allied, and in others to place together such as have no natural affinity."

The principal fossil groups of *Foraminifera* require a brief consideration, but in the short summary of these which follows—as in the case of similar summaries which will subsequently be given—it will be understood that nothing further is proposed than to select for notice and characterisation those *leading types* of each great group of fossils which may seem to demand mention on the ground of their being common, or in other respects, geologically or zoologically, of peculiar importance. For anything like a complete list of the known structural types of each group, or the characters of all the recorded

genera, the specialist will consult special treatises; and it does not appear to be necessary for the wants of ordinary students to do more than to supply a brief statement of the conspicuous characters—especially the *differential* characters—of the more widely distributed and more important types in each group. Nor can even this limited characterisation of leading types be carried out with equal fulness in the case of all groups of fossils, or upon any absolutely uniform plan. In the case, however, of Invertebrate fossils, as being those with which the palæontologist is more especially called upon to deal, the families of each group will, where possible, be defined, and some of the chief generic types will be noticed. The subjoined engraving, representing some of the principal type-forms of the *Foraminifera*, is from a drawing kindly made for the author by his friend, Dr Henry Brady, who has so greatly contributed to our knowledge of this difficult group of organisms.

The first family of the old division of the Imperforate *Foraminifera*, that of the *Gromidæ*, requires no special consideration from a palæontological point of view, as it is not represented by any fossil forms. Most of the *Gromidæ* are inhabitants of fresh waters, and they possess a thin, chitinous, imperforate shell, sometimes encrusted with foreign bodies, and with a general pseudopodial aperture at one or both ends. Owing to the horny character of the shell, it is hardly probable that any members of this family will ever be discovered in the fossil condition.

In the family of the *Miliolidæ*, the test is opaque, porcellanous, unilocular, or multilocular, and extremely variable in shape; the oral aperture being simple and undivided, or being formed by numerous pores. The family, as far as known at present, is not represented in the Palæozoic period, but ranges from the Trias to the Recent period inclusive. One of the simplest forms of this group is *Cornuspira* (fig. 29, *a*), in which the shell is a simple unchambered spiral, like the shell of a *Planorbis*. The genus is represented for the first time in the Lias, and is found under living forms in our seas. *Nubecularia* is a still older type, beginning in the Trias, and its test, extraordinarily variable in shape, is usually parasitic upon shells and other foreign bodies. In *Miliola*, again (fig. 29, *b*, representing the sub-generic form *Quinqueloculina*), the shell is still extremely variable in form, but it consists typically (*Biloculina*) of a series of chambers wound round an axis, in such a manner that each embraces half the entire circumference. This genus dates from the Trias, and is well represented in recent seas. It abounded in Eocene times, one of the Tertiary limestones of the Paris basin being known as the "Miliolite limestone," in consequence of its being largely made up of the shells of a *Miliola*. In *Peneroplis* (fig. 29, *c*), which is closely allied to *Cornuspira*, the shell is a flattened spiral, which

expands very rapidly in its last half turn, the mouth running along the length of the base, and being constituted by numerous isolated

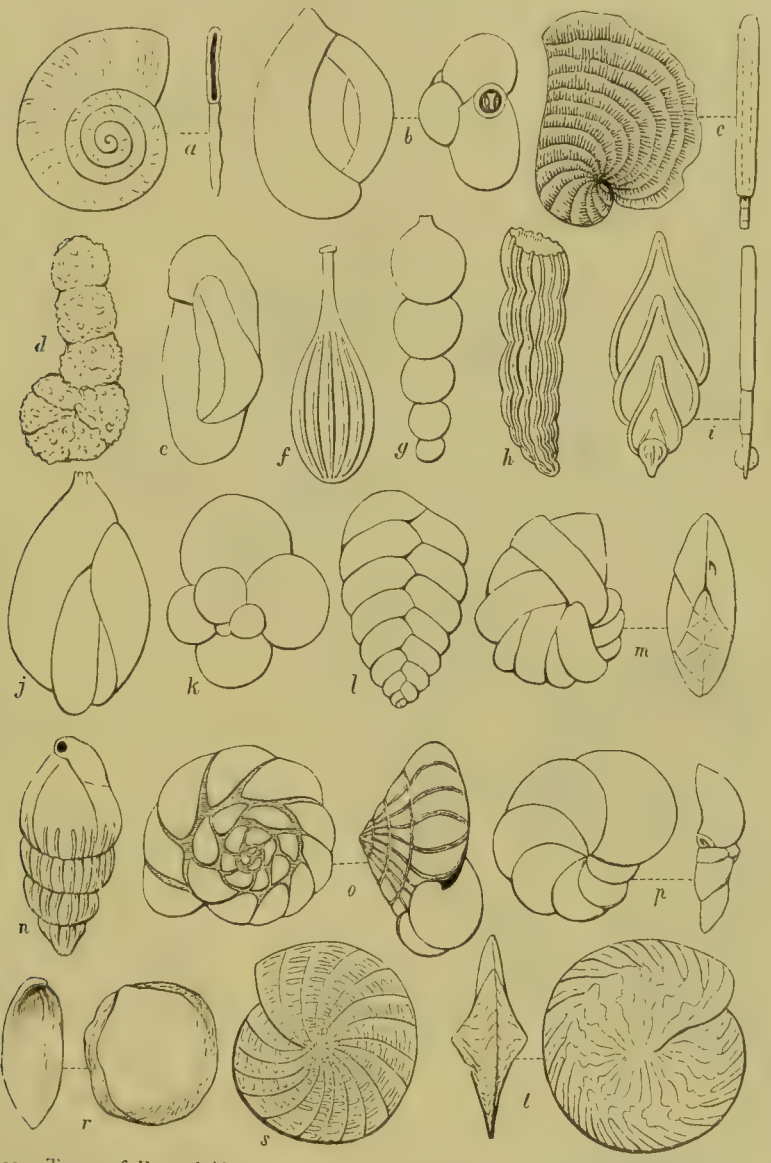


Fig. 29.—Types of Foraminifera. *a, Cornuspira foliacea; b, Quinqueloculina seminulum; c, Peneroplis pertusus; d, Lituola agglutinans; e, Trochammina pusilla; f, Lagena sulcata; g, Nodosaria radicula; h, Marginulina raphanus; i, Frondicularia Archiaciana; j, Polymorphina lactea; k, Globigerina bulloides; l, Textularia sagittula; m, Cassidulina lævigata; n, Bulimina Buchiana; o, Rotalia Beccarii; p, Truncatulina lobatula; r, Archædiscus Karreri; s, Polystomella crispa; t, Amphistegina Lessoni.* All the figures are greatly enlarged, the real diameters varying from 1-100 to 1-10 inch. (H. B. Brady.)

pores. It ranges from the Eocene to the present day. Much more complicated types of the *Miliolidæ* are *Alveolina* and *Orbitolites*.

The former has a comparatively large fusiform shell, consisting of many layers of chambers rolled up spirally round an elongated axis, the last series opening by a row of pores. It dates from the Cretaceous period, and has largely contributed to the formation of various of the Tertiary limestones. The latter is coin-shaped, sometimes more than half an inch in diameter, and very complex as regards the arrangement of its chambers. The genus is especially abundant in the Eocene Tertiary, but it dates from the Lias, and occurs plentifully in recent seas.

The next family of the *Foraminifera* is that of the *Astrorhizidæ*, comprising a number of interesting types, sometimes of considerable size, in which the test is composed of sand-grains or other foreign particles, generally united by a cementing basis, but sometimes slightly or not at all consolidated. The test may be monothalamous or polythalamous, but in the latter case genuine internal septa do not exist. The shell is often branched or radiate, and may attain a considerable size. The type-genus of this family is *Astrorhiza* itself (fig. 19, A), which is not known to occur in the fossil condition, its test, though of considerable thickness, having its component grains very imperfectly cemented together. A much firmer and more compact shell is possessed by the genus *Saccammina*, which merits special mention as being the only Foraminifer which in Britain can be said to actually form a limestone. It consists of free spherical, pyriform, or fusiform chambers (fig. 30), sometimes separate, sometimes united end to end in twos or threes, with thick, internally labyrinthic walls. The central chamber communicates with the exterior by a single aperture, and the average length of the chambers of the British Carboniferous species (*Saccammina Carteri*, Brady) is as much as 1-8th inch. It forms beds of limestone in the Carboniferous of the South of Scotland and North of England; but the genus is not known to occur again till we meet it in the Post-Pliocene, and, in a living state, in the North Sea. The genus is, however, of a much higher antiquity than the Carboniferous, since it is found to be largely represented in the Ordovician limestones of Ayrshire.

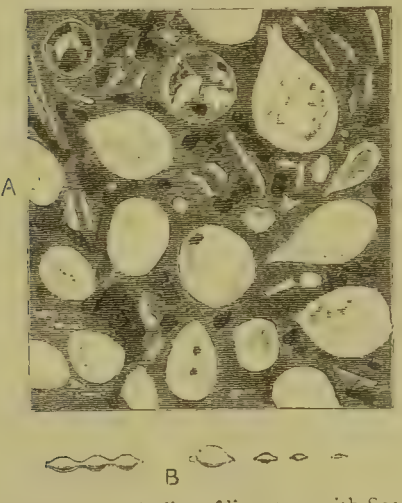


Fig. 30.—A, A slice of limestone with *Saccammina Carteri*, enlarged five diameters, from the Carboniferous Limestone of Elfhills, Northumberland. (After H. B. Brady.) B, Spheres of the same, of the natural size, exhibiting variations.

In a number of very interesting forms of the *Astrorhizidæ*, the test

is tubular, composed of arenaceous tubes, of which the sand-grains may be loosely or firmly cemented together, and which may be free or may be adherent along one side to foreign bodies. The tubular test may be branched or radiate, or may simply be more or less loosely coiled and contorted. One of the most remarkable recent types of this group is *Syringammina*, in which the test is described by Dr Brady as forming masses of branching, radiating tubes, arranged in more or less distinct layers or tiers. In *Hyperammina*, again, the test (fig. 31) has the form of a sandy tube, often of indefinite length,



Fig. 31.—The winding tubular test of *Hyperammina vagans*, adherent on one side to a piece of broken shell. *a* Initial chamber; *b* General pseudopodial aperture. The figure is enlarged fifteen diameters. Recent. (After H. B. Brady.)

with the closed end commonly inflated so as to form a distinct chamber, the pseudopodia being emitted from a general aperture at the opposite end of the tube. The tube in this genus may be free, or may be adherent to foreign bodies.

The forms just mentioned throw light upon some very remarkable fossils which occur in great numbers in certain of the Ordovician limestones of Britain and North America, and which have been described under the generic name of *Girvanella* (= *Strephochetus*). The fossils in question present themselves in the form of small rounded or irregular nodules (fig. 32, A), which are sometimes so abundant as to constitute a conspicuous element in the limestone. When broken, these nodules show a distinctly concentric structure, and when examined by means of thin sections (fig. 32, B), they are found to consist of exceedingly minute circular tubes (about 1-45 millimetre in diameter), endlessly contorted and bent, and twisted

together in loosely reticulate or vermiculate aggregations. The most probable view of the relationships of this singular fossil is that it is an

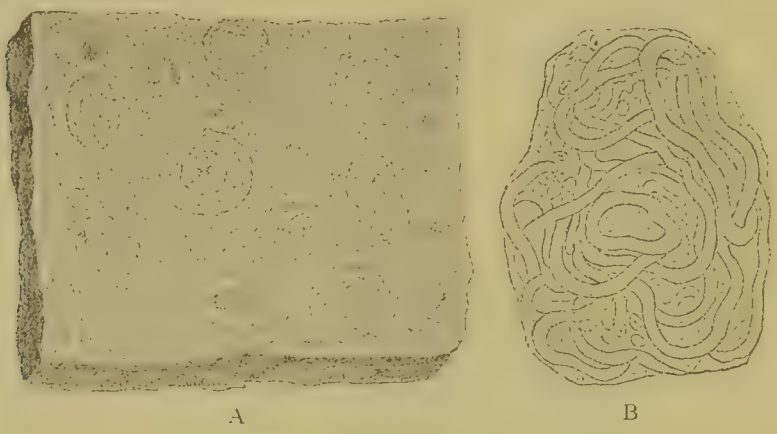


Fig. 32.—A, Fragment of limestone from the Ordovician rocks of Craighead, Girvan, of the natural size, showing numerous exceptionally large masses of *Girvanella problematica*; B, Section of a minute mass of *Girvanella*, enlarged about sixty times. (Original.)

Arenaceous Foraminifer, allied to the recent genera *Syringammina* and *Hyperammina*.

The last group of the so-called "Imperforate" *Foraminifera* is that of the *Lituolidæ*, comprising an extensive series of arenaceous types, in which the shell consists essentially of particles of coarse or fine sand cemented together more or less firmly. In many cases the cement is calcareous, and though the shell is usually imperforate, the walls are in other cases pierced by pseudopodial apertures. Sometimes the test consists of purely calcareous particles embedded in a calcareous cement. In *Lituola* itself, the type of the group (fig. 29, *d*), the test is generally crosier-shaped, sometimes nautiloid, usually with a rough exterior, and composed of sand-grains agglutinated together. The genus ranges from the Carboniferous to the present day. An essentially Carboniferous type is *Endothyra*, in which the shell is nautiloid, or resembles that of a *Rotalia* in shape, and is found abundantly in the Mountain Limestone of Britain. It forms in America entire beds of the Carboniferous Limestone (fig. 33). Allied to *Endothyra* is the Liassic

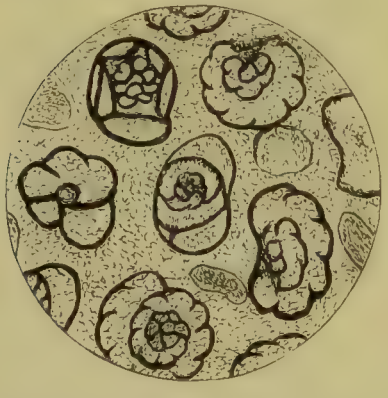


Fig. 33. –Section of Carboniferous Limestone from Spergen Hill, Indiana, U.S., showing numerous large-sized *Foraminifera* (*Endothyra*) and a few oolitic grains magnified. (Original.)

genus *Involutina*, formerly placed among the Rotaline Foraminifera. In *Trochammina* (fig. 29, *e*) the test is usually spiral, consisting of one or many chambers, free or attached, and, though sandy, with a smooth surface. It ranges from the Carboniferous to the present day. *Valvulina* (fig. 34) also generally has a spiral shell which may be free or attached, and is normally thick-walled, imperforate, and sandy. Sometimes, however, the shell is porous and smooth, and in other cases the sandy coating seems to be a mere encrustation on a calcareous and perforate shell, so that *Valvulina* (which is by Brady included in the family of the *Textularidæ*) may be regarded as a transitional type between the series of the imperforate and perforate *Foraminifera*. The genus makes its first appearance in the Carboniferous of Britain, is abundant in the Tertiaries, and is represented in existing seas. In the *Nodosinella* of the Carboniferous we have another curious type, closely resembling the well-known *Nodosaria* in *form*, but having a sub-arenaceous, imperforate test. A still more singular form is the *Stacheia* of the Carboniferous, in which the test is also sub-arenaceous and imperforate, but grows parasitically upon foreign bodies, in the shape of a crust composed of "an acervuline mass of chamberlets" (Brady). Lastly, there is a peculiar group of the *Lituolidæ* represented by the recent *Cyclammina* and the extinct *Loftusia*, in which the test is sandy, and the finely arenaceous shell-wall is irregularly cancellated, so as greatly to restrict the actual cavities of the chambers. In *Cyclammina* the shell is spiral and nautiloid, with numerous chambers arranged in an involute series. In the singular genus *Loftusia* (fig. 35), from the Eocene Tertiary of Persia, the test is fusiform, and may attain a length of from two to three inches. As regards its internal structure, the shell is composed of a spirally rolled lamella, the volutions of which run in the long axis of the test, and which is of a sandy texture and is much cancellated (fig. 35, B). The spaces between the volutions of the primary lamella are intersected by obliquely directed partitions, which are also cancellated in structure, and are connected by numerous irregular vertical pillars.

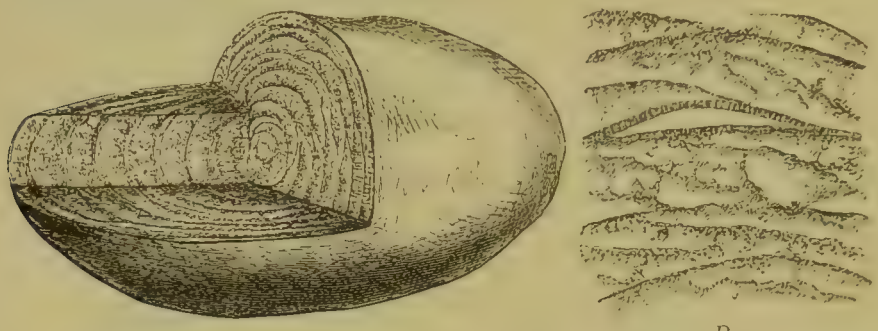


Fig. 34.—A, *Valvulina palæotrochus*, viewed in profile, and enlarged 45 diameters; B, The same viewed from below. Carboniferous Limestone. (After Brady.)

The genus *Parkeria*, which has commonly been referred here, has been shown by recent investigations to be truly referable to the *Hydrozoa*, and to be related to the existing *Hydractinia*.

Coming next to the great series of forms which have usually been

grouped together under the name of "Perforate Foraminifera," the first family we have to deal with is that of the *Textularidæ*, in which the test may be arenaceous or calcareous, but usually possesses a perforate calcareous basis. The smaller forms of the family have a



A B

Fig. 35.—A, A specimen of *Loftusia persica*, from the Eocene of Persia, of the natural size, cut open to show its general plan of structure. (After Brady.) B, Portion of a vertical section of *Loftusia*, showing the minute structure of the test, enlarged about ten times. (Original.)

hyaline calcareous shell, with large pseudopodial foramina. The chambers are usually arranged in two or more alternating series, generally in a straight line, but sometimes in a spiral. In many cases (*e.g.*, in *Bigenerina*) the test is dimorphous, the first-formed chambers being in a double series, while the later ones are uniserial. In *Textularia* itself (figs. 29, *l*, and 36) the test is generally conical or wedge-shaped, and consists of numerous chambers arranged in two alternate parallel series. *Bigenerina* is much the same as *Textularia*, except that the last-formed segments are disposed in a single and not a double series; and both make their first appearance in the Carboniferous, the latter being a common type in many formations and being specially abundant in the Chalk. *Bulimina* (fig. 29, *n*), dating from the Trias (Rhætic) onwards, consists of spheroidal segments which progressively increase in size, and form an oblique spiral; while *Cassidulina* (fig. 29, *m*), ranging from the Miocene to the present day, though truly biserial, is more or less completely rolled up, and may thus be regarded as an involute *Textularia*. Lastly, *Chrysidalina*, dating from the Chalk, is like *Textularia*, but is triserial.



Fig. 36.—*Textularia Meyeriana*. D'Orbigny.

Closely related to the Textularians are the forms included in the small group of the *Chilostomellidæ*, in which the test is many-chambered, calcareous, and finely perforate. The segments follow

each other from the same end of the long axis, or alternately at the two ends, or in cycles of three, and the one last formed more or less completely embraces those previously formed. In *Chilostomella* itself, the segments are oval, and each entirely envelops the previous one; whereas in *Allomorphina*, the chambers alternate at three sides so as to leave portions of two, in addition to the last one, exposed to view. The former genus is confined to the Tertiary deposits, and the latter is Cretaceous and Tertiary.

The great family of the *Lagenidæ* comprises "hyaline" or "vitreous" *Foraminifera*, with a calcareous shell, the walls of which are pierced by numerous *minute* pores, and are usually more or less strikingly thin and glassy. In the compound forms of this group the successive chambers have their posterior walls formed by the front wall of the preceding segment, so that the septa are always single, instead of being double, and there is never any "intermediate" skeleton. The family may be divided into two series, *Lagena* itself being the type of the one, while *Nodosaria* is the type of the other. In *Lagena* (fig. 29, *f*) the shell is simple, flask-shaped, unilocular, with a single prominent aperture. The genus commences in the Silurian, with forms little different from, or identical with, existing types, is further developed in the Secondary and Tertiary, and is well represented at the present day. *Polymorphina* (fig. 29, *j*) is allied to *Lagena*, but it is multilocular, the chambers being usually arranged in a double series. It is represented in the Trias, and survives under common types at the present day. In the series of which *Nodosaria* is the type, we have perforate Foraminifera consisting of a succession of chambers, each of which is essentially similar to a *Lagena*, arranged in a series, which is usually nearly or quite straight, though sometimes spirally involuted. In *Nodosaria* itself (fig. 29, *g*) the chambers are simple, and are disposed in a straight line. It ranges from the Permian to the present day. *Dentalina*, ranging from the Carboniferous onwards, is fundamentally like *Nodosaria*, but the shell is bent like a bow. *Vaginulina* comprises forms similar to *Nodosaria*, but laterally compressed, and begins in the Trias (Rhætic). *Marginulina* (fig. 29, *h*) is slightly curved, or is sometimes crosier-shaped, and also starts in the Trias. *Frondicularia* (fig. 29, *i*) has the shell flattened out and leaf-like, and likewise makes its first appearance at the summit of the Trias. Lastly, *Cristellaria* (with *Robulina*) comprises forms more or less spirally inrolled or crosier-shaped, which extend from the Trias to the present day, and have a very wide development both individually and specifically.

In the family of the *Globigerinidæ*, Dr Carpenter included all those hyaline *Foraminifera*, in which the calcareous shell is perforated by large-sized pseudopodial foramina, but the group, as defined

by Dr H. B. Brady, is a much more restricted one. The test is always calcareous and perforate, and consists of a few inflated chambers arranged spirally, or of a single chamber only. There is no "supplementary skeleton," and there is a large single or multiple "general aperture" to the shell. The apparently simplest form of the *Globigerinidæ* is *Orbulina* (fig. 22), in which the test has the external form of a single globular chamber, the walls of which are perforated by a double series of foramina, large and small. It seems more than doubtful if the test, as represented in fig. 22, possesses any "general aperture." Doubt has been thrown upon the true relationships of *Orbulina* by the discovery that in many specimens, especially in those of small size, the apparently monothalamous sphere contains in its interior a young *Globigerina*-shell, attached to the inside of the wall by slender spicules. It has therefore been held that *Orbulina* is really a form of *Globigerina* in which the last chamber includes all those previously formed. The genus *Orbulina* has a world-wide distribution at the present day, and its earliest representatives appear in deposits as old as the Trias (Rhætic). The genus *Ovulites*, formerly placed in the immediate neighbourhood of *Orbulina*, appears, according to recent researches, to be in reality a Calcareous Alga. The only other member of the *Globigerinidæ* which requires notice is the type-genus *Globigerina* itself (fig. 29, *k*), in which the test is polythalamous and coarsely perforated (fig. 20). The chambers are few in number, and globose in form, and are usually arranged in a turbinate spiral, thus resembling the shell of a *Rotalia*. The chambers do not communicate with one another directly, but each opens by a special aperture into a deep central or umbilical depression. In pelagic forms (as also in *Orbulina*) the test, when perfect, appears to be covered with long and extremely delicate spines. *Globigerina* dates from the Trias, and is extremely abundant. It is of special interest, as being the principal constituent of the "ooze" (fig. 27) found at great depths in the larger oceans at the present day; while its shells form an equally large portion of the White Chalk (see p. 119).

In the large and important family of the *Rotalidæ*, the test is typically composed "of a succession of coarsely porous or globigerine segments, arranged in a turbinoid spire, and communicating with each other by a crescentic aperture situated at the junction of the septal plane with the free surface of the convolution" (Carpenter). The segments of the shell are typically so coiled that the whole of the chambers are exposed to view on the upper surface, whereas on the under side only the last convolution is visible, different types varying as to which side of the shell is the more convex. The shell-structure may be simple, but in other cases the test is

complex and is furnished with a "supplemental skeleton" and "canal-system" (fig. 21). Among the typical Rotaline forms, the genus *Discorbina*, with its coarsely porous shell, dates from the Chalk, and is found living in our seas. *Pulvinulina* (fig. 24), on the other hand, with a more finely porous shell, has been detected by Brady in rocks of Carboniferous age, and is thus one of the earliest representatives of the Rotalines. In *Rotalia* itself (figs. 21 and 29, *o*), the test is also spiral and turbinoid, but its structure is more complex than in the preceding, the shell-substance being compact and very finely porous; while each chamber is enclosed by a complete wall of its own, and there are canal-like spaces between the two lamellæ forming each septum. In these respects, *Rotalia* closely approaches the Nummuline type. The earliest *Rotaliæ* appear in the Jurassic, but the genus attains its maximum in the Tertiary period, and is well represented at the present day. The approximation to the Nummuline type is further manifested by *Calcarina* (fig. 26, B and C), in which the shell is spiral and discoidal, with spur-like marginal appendages, and with a well-developed "supplemental skeleton" and "canal-sytem." The genus has been shown by Brady to commence in the Carboniferous. In *Planorbulina* the shell is composed of numerous segments, at first spirally and then cyclically disposed. It dates from the Tertiary period, but the forms which are included under the sub-generic name of *Truncatulina* (fig. 29, *p*) commence in the Carboniferous. *Tinoporus*, dating from the Chalk, is in some respects intermediate between *Calcarina* and *Planorbulina*, its general form being like that of the former, while the irregular and partly cyclical arrangement of its chambers recalls the latter. No "general aperture" is present, but a "supplemental skeleton" and "canal-system" are developed, both of these structures being wanting in the allied *Gypsina*. Though not known in the fossil condition, the genus *Polytrema* may be alluded to here, since it has some curious resemblances to certain of the *Polyzoa*. It forms crusts, or, more commonly, branched outgrowths, parasitically attached to foreign bodies; and it consists of numerous intercommunicating irregular chambers, the walls of which are penetrated by an extensive system of capillary canals, a true canal-system being, however, absent. *Polytrema* seems to be the representative in the Rotaline series of the singular genus *Stacheia* among the *Imperforata*. Lastly, an aberrant type of the Rotalines is constituted by the genus *Spirillina*, in which the test has the form of a calcareous tube, without any internal partitions, coiled into a flat spiral, and either free or attached to some foreign body. The genus begins in the Tertiary rocks, and is represented by living forms.

Finally, we have the family of the *Nummulinidæ*, comprising the

most complex and the most highly organised of all the *Foraminifera*. In the forms included under this head, the shell is compound; the successive chambers are enclosed each in its proper wall (as diagrammatically shown in fig. 26, A); there is generally a well-developed "intermediate" or "supplemental" skeleton, which renders the shell strong and compact, and which is perforated by a "canal-system," originating in the spaces between the two lamellæ composing each septum; while the shell-substance is pierced by close-set and extremely fine tubules (fig. 37), the septa alone wanting these, so

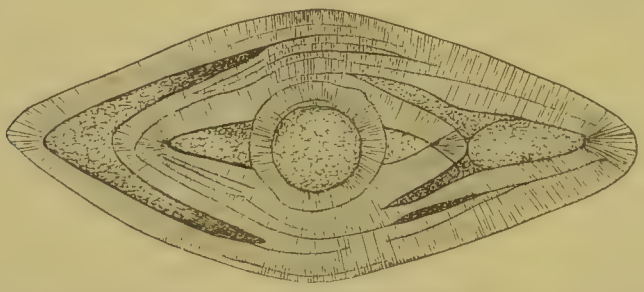


Fig. 37.—Transverse section of the test of *Nummulina pristina*, from the Carboniferous Limestone, enlarged 100 diameters, showing the primordial chamber and the tubulated shell-wall. (After H. B. Brady.)

that contiguous chambers usually communicate by but one large aperture. The lower forms of the family have a thickened and finely tubulated shell-wall, but have no intermediate skeleton. The form of the shell is typically a discoidal spiral or a cycloidal disc.

There is a relationship of a decided character between the higher Rotalines and the *Nummulinidæ*, as exhibited by forms like *Rotalia* itself, and *Calcarina* on the one hand, and by *Polystomella* and *Amphistegina* on the other hand. In *Polystomella* (fig. 29, *s*) the shell is lenticular and discoidal, and is composed of successive chambers, which are prolonged into wing-like ("alar") prolongations, which extend inwards to the centre, thus concealing the earlier turns of the spire from view, while the centre itself is occupied by a solid calcareous boss, penetrated by irregular canals. The "canal-system" is extraordinarily developed and very complex. Some of the simpler types of *Polystomella* are grouped together under the name of *Nonionina*; and the genus seems to make its first appearance in the Upper Chalk, being well represented in the Tertiaries, and surviving to the present day.

Amphistegina still more closely approaches the Rotalines, with which it has sometimes been grouped. Its shell is spiral and discoidal (fig. 29, *t*), usually more or less inequilateral, each chamber being saddle-shaped, and sending forth "alar" prolongations which reach nearly to the centre, where is placed a solid boss. The shell-substance, with exception of the septa and the central boss, is pene-

trated by numerous close-set, parallel, extremely minute tubules, but the "canal-system" is only imperfectly developed. Brady has shown that the genus occurs in the Carboniferous; but with this exception it is Tertiary and Recent.

Another very ancient, and more anomalous, type of the Nummuline group is the *Archædiscus* of Dr Brady (fig. 29, *r*), which occurs also in the Carboniferous Limestone. In this curious form the test is "convoluted, rounded, more or less unsymmetrical; formed of a non-septate tube coiled upon itself in a constantly varying direction; the shell-wall transversed by very numerous parallel minute tubuli" (Brady).

In the genus *Nummulina* itself (fig. 38) the shell is coin-shaped, of large size, sometimes as big as a florin, or larger, composed of

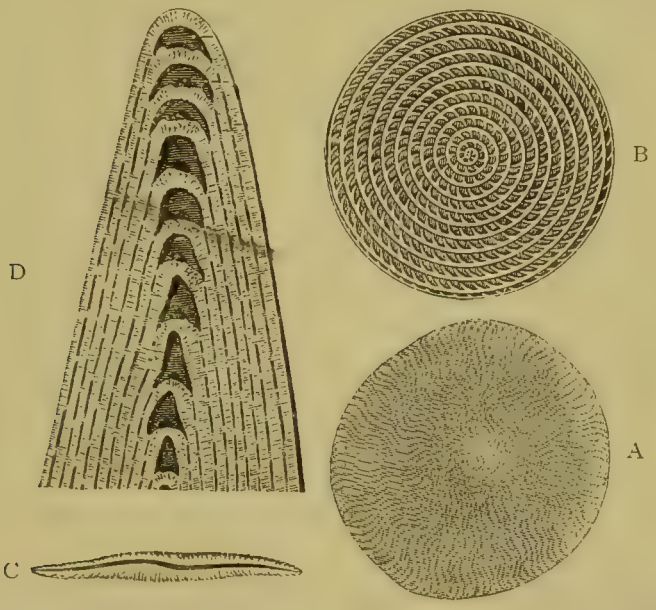


Fig. 38.—*Nummulina nummularia.* A, The shell viewed from above; B, The same horizontally bisected; C, The same vertically bisected; D, Vertical section of part of the shell, highly magnified, showing the chambers of the median plane, the alar prolongations, and the tubuli of the shell-substance. Eocene Tertiary.

numerous chambers arranged on one plane in a regular spiral. Each chamber is saddle-shaped, the internal or "alar" prolongations of each extending to the centre, so that each revolution completely encloses and conceals from view all the preceding ones. The successive chambers communicate by means of arched fissures, which perforate each septum, close to the periphery of the previous turn of the spire, while secondary and irregular pores in the septa discharge the same function. The general shell-substance is traversed by extremely minute parallel tubuli (fig. 38, D, and fig. 37); and there is

a supplemental skeleton (forming the so-called "marginal cord"), which, together with the septa, is penetrated by a well-developed and ramified "canal-system" (see fig. 26, D). By the researches of Brady, we know now that the range of the genus *Nummulina* in time must be carried back to the Carboniferous, one small form (viz., *Nummulina pristina*, fig. 37) having been detected in the Mountain Limestone of Belgium. A few "Nummulites" have also been detected in strata of Jurassic and Cretaceous age, but the maximum development of the genus is recorded in the early Tertiary period (Middle Eocene). At this period in the earth's history we find the Nummulites existing in extraordinary profusion, and building up the widespread and massive series of calcareous deposits which are known as the "Nummulitic Limestone." According to Sir Charles Lyell, "the Nummulitic Limestone, with its characteristic fossils, plays a far more conspicuous part than any other Tertiary group in the solid framework of the earth's crust, whether in Europe, Asia, or Africa. It often attains a thickness of many thousand feet, and extends from the Alps to the Carpathians, and is in full force in the north of Africa, as in Algeria or Morocco. It has also been traced from Egypt, where it was largely quarried of old for the building of the Pyramids, into Asia Minor, and across Persia, by Bagdad, to the mouths of the Indus. It occurs not only in Cutch, but in the mountain-ranges which separate Scinde from Persia, and which form the passes leading to Cabul; and it has been followed still further eastwards into India, as far as Eastern Bengal and the frontiers of China." In the later Tertiary period, the genus underwent a striking degeneration; and it is represented at the present day by only a few small forms, which are found in arctic, temperate, and tropical seas.

Very closely allied to *Nummulina*, and of equal or even greater geological importance, is the genus *Fusulina*, the typical forms of which (fig. 39) are spindle-shaped in figure, and may be compared to a Nummulite drawn out at its umbilici. According to Brady, however, some species of *Fusulina* are discoidal and symmetrical, and thus not distinguishable in *form* from *Nummulina*; while in other species the test is spherical. In internal structure, and especially in the minute tubulation of the shell-substance, the genus approaches *Nummulina*, but a regular interseptal "canal-system" appears to be wanting, and the chambers are broken up into chamberlets. Most of the *Fusulinæ* are of considerable size, often from a third to a half of an inch in length, and they often constitute massive beds of limestone, which have been justly paralleled

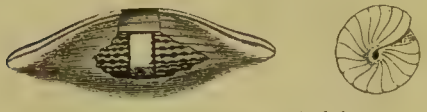


Fig. 39.—*Fusulina cylindrica*. Carboniferous, Russia.

with the Nummulitic Limestone of the Eocene. Thus they form whole beds of the Carboniferous Limestone in Russia, Central Europe, Armenia, India, China, Japan, and the United States. Though pre-eminently Carboniferous, they occur also in the Permian.

The remaining types of the *Nummulinida* can be merely alluded to here. The genus *Orbitoides* is extremely like *Nummulina* in external appearance and form, and has been often mistaken for it, but it differs considerably in its internal structure, and especially in the fact that its mode of growth is cyclical instead of spiral, and the place of the "alar prolongations" of the chambers of the latter is taken by a multitude of chamberlets. The genus appears first at the summit of the Cretaceous, but it undergoes, along with its ally *Nummulina*, an extraordinary development in the early Tertiary period, and it forms immense masses of Eocene limestone in the Southern United States, the West Indies, and in various parts of the Old World. A nearly allied genus is *Cycloclypeus*, which is also coin-shaped, and is strictly cyclical in its mode of growth. It occurs in the Miocene Tertiary, and the only known recent types attain an extraordinary size (over two inches in diameter). *Operculina*, again, is much more closely related to *Nummulina* proper in its internal structure, though it differs in *form*, owing to the fact that the chambers of the spirally inrolled shell have no "alar prolongations," and thus approximate to the Rotaline type. The genus commences in the Upper Cretaceous, but is particularly developed in the Eocene of the South of Europe and Africa. Lastly, *Heterostegina* (Tertiary and Recent) differs from *Operculina* chiefly in having the principal chambers broken up into chamberlets by secondary septa.

APPENDIX TO FORAMINIFERA.

Eozoön Canadense.

In connection with the subject of the *Foraminifera*, it is necessary to consider the structure and probable nature of the singular body to which the name of *Eozoön* has been given, since this body, if organic at all, must be regarded as referable to the foregoing group of organisms. There is, in fact, a special, twofold interest attaching to *Eozoön*, if it should be proved that the body so named is truly organic. In that case, *Eozoön* would, on the one hand, be the most ancient type of life which has yet been detected by the researches of palæontologists, while, in the second place, it would present us with a type of *Foraminifera* of colossal size, and in other respects of quite peculiar zoological interest. Since the whole subject of the structure and relations of *Eozoön* is one of great complexity, it would not be advisable to deal with it here in any detailed manner, or to enter into the long and still unfinished controversy which has been carried on as to the organic or inorganic nature of this remarkable body. It will be sufficient to briefly describe the general form and

mode of occurrence of *Eozoön*, the chief structural features which it presents in thin sections, and the general explanation of these features given respectively by those who regard it as Foraminiferal and those who consider it to be a purely mineral structure. In addition, it may not be out of place to indicate a few considerations based upon a prolonged and careful microscopical investigation which the present writer has independently carried out into the structure of this problematical body.

The peculiar structure which has been described under the name of *Eozoön Canadense* occurs in the crystalline metamorphic limestones of the Lower Laurentian in Canada, and it has also been detected in the same country in similar limestones believed to be of the age of the Upper Laurentian or Huronian. An allied form (species?) has been found in rocks supposed to be Laurentian in Newfoundland; and Dr Gümbel has described a third form from crystalline limestone belonging to the "Hercynian gneiss formation" (Lower Cambrian or Huronian?) of Bavaria.

As regards its mode of occurrence, *Eozoön* appears to most commonly present itself in the form of spreading layers or confluent masses. According to Sir William Dawson, however, comparatively small, isolated specimens are found, which have a "broadly-turbinate, funnel-shaped, or top-shaped form, sometimes with a depression on the upper surface." The same observer has also described the occurrence of vertical tubes of large size traversing masses of *Eozoön*, and has compared these with the oscular canals of Sponges.

As regards its *macroscopic* characters, a mass of *Eozoön* shows a conspicuous structure out of thin alternating laminæ, arranged parallel with one another and often more or less concentrically (fig. 40). The laminæ

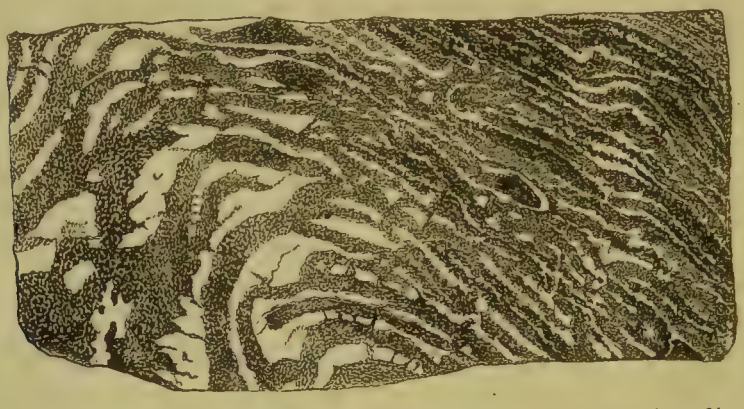


Fig. 40.—Fragment of *Eozoön*, of the natural size, showing alternating laminæ of loganite and dolomite. (After Dawson.)

of such a mass are usually of different colours and composition; one series being white, and composed of carbonate of lime — whilst the laminæ of the second series alternate with the preceding, are green in colour, and are found by chemical analysis to consist of some silicate, generally serpentine or the closely related "loganite," or white pyroxene. In some instances, however, according to Dawson, all the laminæ are calcareous, the concentric arrangement still remaining visible in consequence of the fact that the laminæ are composed alternately of lighter and darker coloured limestone. The calcareous layers (fig. 41, A) are composed of coarsely crystalline calcite (as viewed macroscopically), and

vary much in thickness, not only in different specimens, but commonly in different parts of the same specimen. According to Dawson, in isolated, inversely conical specimens it is the laminæ at the base which are the thickest. Very commonly, the laminæ subdivide and coalesce with one another. The serpentinous layers, which alternate with the calcareous laminæ, usually show a more or less conspicuous structure

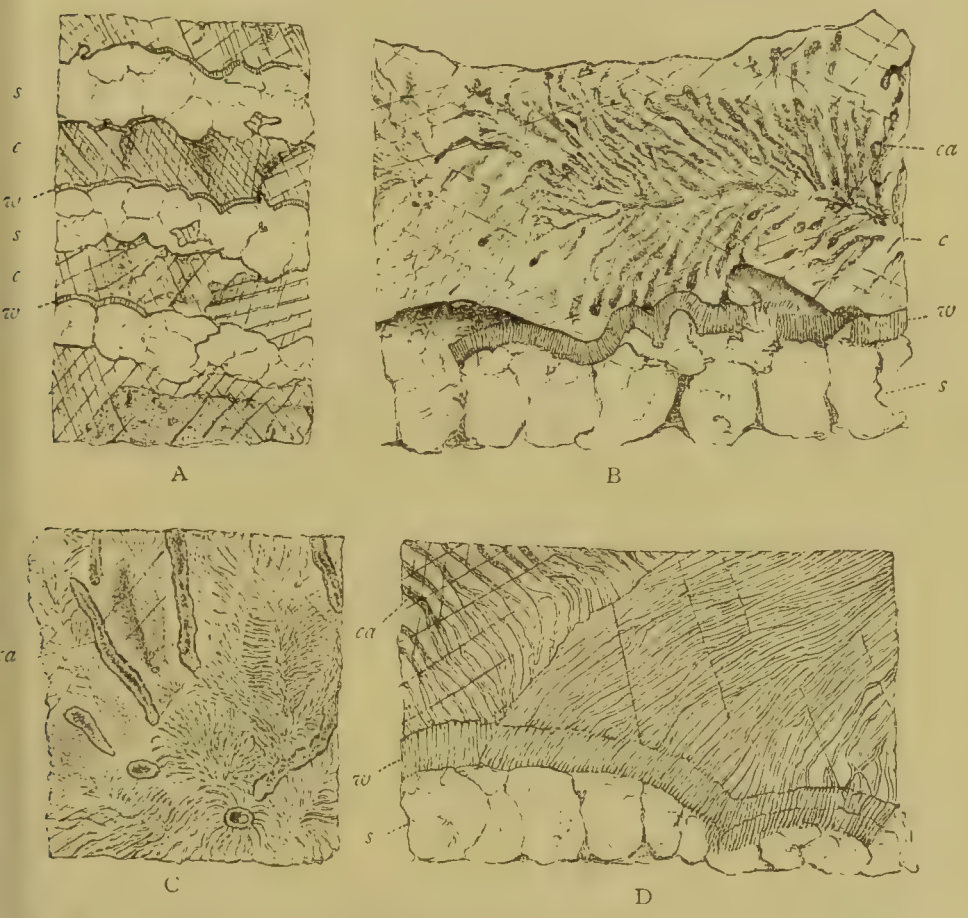


Fig. 41.—Minute structure of *Eozoön Canadense*, from the Laurentian limestones of Canada. A, Part of a vertical section of *Eozoön*, enlarged about ten times, showing the alternating layers of calcite (*c*) and serpentine (*s*); B, Part of a calcareous lamina, cut vertically, showing the "canal-system," enlarged about forty-five times; C, Part of a calcareous lamina, cut horizontally, and enlarged about sixty times, showing the large and small branches of the canal-system; D, Part of a vertical section of a calcareous lamina, enlarged about one hundred times, showing the finer divisions of the canal-system and the so-called "proper wall" (*w*). *c*, Calcareous laminæ; *s*, Serpentinous laminæ; *w*, The so-called "proper wall"; *ca*, Large branches of the canal-system. (Original.)

out of small rounded or lenticular masses. This characteristic botryoidal structure of the serpentinous laminæ is best studied in polished specimens which have been treated with weak acids, so as to dissolve out the calcareous portions of the mass to a limited depth below the surface.

As regards the *microscopic* structure of *Eozoön*, the calcareous laminæ, in well-preserved examples, exhibit a very remarkable canaliculated or

tubulated structure. In parts in which this structure is preserved, the crystalline calcite of the calcareous laminæ is seen to be traversed by branching and dendritic canals (fig. 41, B and C). Some of these canals (fig. 41, B) are of comparatively large size, and these are generally more or less extensively occupied with an infilling of serpentine, though sometimes partially filled with calcite. In connection with these large canals are much more delicate canaliculi or tubules (fig. 41, C and D), which run more or less parallel with one another, or have a tufted arrangement, and which are commonly filled with transparent *calcite*. At the edges of the calcareous laminæ these delicate and branching tubules often appear to terminate in a narrow belt or selvage (the so-called "proper wall" or "Nummuline layer" of Carpenter and Dawson), which has a transversely striated aspect, as if composed of parallel fibres or traversed by innumer-

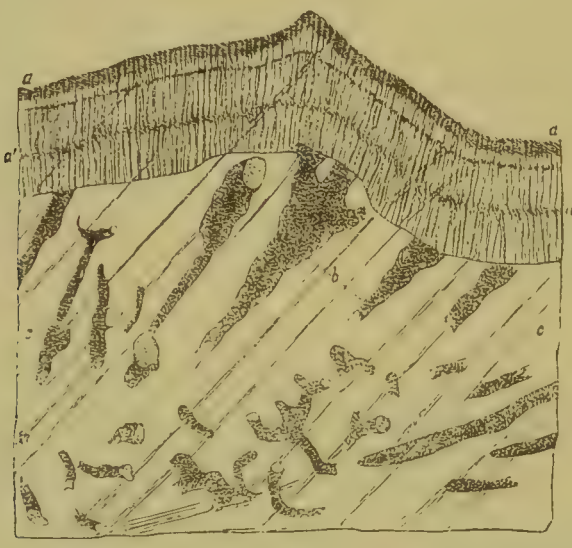


Fig. 42.—Portion of one of the calcareous layers of *Eozoön*, magnified 100 diameters. *a a*, The proper wall ("Nummuline layer") of one of the chambers, showing the fine vertical tubuli with which it is penetrated, and which are slightly bent along the line *a' a'*; *c c*, The intermediate skeleton, with numerous branched canals. The oblique lines are the cleavage-planes of the carbonate of lime, extending across both the intermediate skeleton and the proper wall. (After Carpenter.)

able minute tubuli (fig. 41, D, *w*). According to the observations of Dawson, this narrow selvage, or "proper wall," consists of "finely divided tubes, similar to those of the canal-system, and composed of its finer subdivisions placed close together so as to become approximately parallel" (fig. 42).

The actual *structure* of *Eozoön* being as above briefly described, we may in the next place shortly consider the interpretation placed upon this structure by those who regard it as organic in origin, and who, like W. B. Carpenter, Dawson, and Rupert Jones, consider it to represent an ancient type of the *Foraminifera*. Upon this view—which a reference to the subjoined diagrammatic figure (fig. 43) will render readily intelligible—the calcareous laminæ (*b b*) of a mass of *Eozoön* represent the original calcareous skeleton of a gigantic Foraminifer, while the serpentinous layers represent the successive tiers of chambers separating successive laminæ of the skeleton. The calcareous skeleton itself has been largely

crystallised or otherwise altered by the metamorphic agencies which have affected the entire mass of the enclosing rock; and the original chambers between successive layers of the shell have been filled up with serpentine or some other silicate, which has taken the place of the living matter which, to begin with, is supposed to have occupied these spaces. The serpentinous infilling has been deposited from solution in water, and has not only usually occupied the large chambers between the calcareous laminæ, but has also more or less extensively penetrated into the larger canals or even the minuter tubuli which traverse the substance of these laminæ. Placing this interpretation upon the observed structure of *Eozoön*, the central and principal portion of each calcareous lamina (fig. 43, *b b*) is regarded as corresponding with the "supplemental skeleton" of such a Foraminifer as *Calcarina* or *Nummulina*, while the branching tubes which traverse the lamina (fig. 43, *d*), are considered to represent the "canal-system" of the same. Moreover, the narrow, transversely striated band or selvage, which normally bounds each calcareous lamina above and below (fig. 43, *a a*), is regarded as corresponding with the "proper wall" of such a Foraminifer as *Nummulina*, and has therefore been commonly spoken of as the "Nummuline layer." On this view, therefore, the so-called "proper wall" is part of the actual skeleton, and the vertical lines which traverse it represent minute tubules, which open into the chambers and on the surface by correspondingly fine pores. It need only be added that if the above explanation of the observed structure of *Eozoön* be accepted, it then takes its place in the series of the *Foraminifera* as a gigantic and aberrant member of the *Nummulinidæ*, having a quite special interest and importance as both the oldest known fossil and also the largest of known Protozoans.

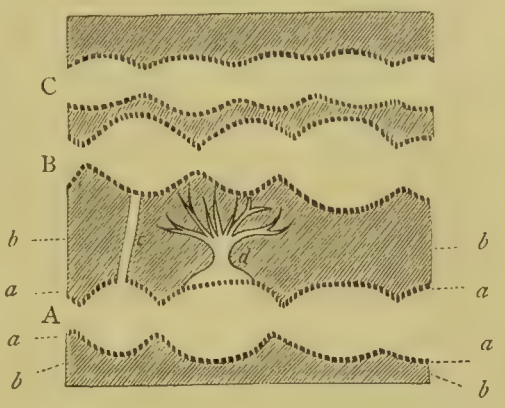


Fig. 43.—Diagram of a portion of *Eozoön* cut vertically. A, B, C, Three tiers of chambers communicating with one another by slightly constricted apertures; *a a*, The true shell-wall, perforated by numerous delicate tubes; *b b*, The main calcareous skeleton ("intermediate skeleton"); *c*, Passage of communication ("stolon-passage") from one tier of chambers to another; *d*, Ramifying tubes in the calcareous skeleton. (After Carpenter.)

On the other hand, very weighty objections have been urged against the theory of the organic nature of *Eozoön* by many observers, and more especially by Möbius in Germany and King and Rowney in Britain.

It would be out of place here to attempt to discuss these objections, but the following are, in brief, the more important arguments which have been brought forward against the organic nature of *Eozoön* and in favour of the view that it is a purely mineral structure:—

a. The structure to which the name of *Eozoön* is applied is found in highly crystalline rocks, and in parts of these which are much broken and altered. Moreover, no unquestionable organic remains have been discovered in association with *Eozoön*.

b. The general form of *Eozoön* is very irregular, and though its minute structure (supposing it to be organic) would show that it belongs to the

Foraminifera, it cannot be closely compared with any known type, recent or extinct, belonging to this group of organisms.

c. The thickness of the calcareous laminæ of *Eozoön* is not only very variable in different specimens, but is liable to great variation even in a single specimen. On the supposition, however, that the calcareous laminæ represent the layers of the skeleton of a Foraminifer or other calcareous organism, it would seem very improbable that such great variations in their thickness should be found to exist.

d. On the hypothesis of the organic nature of *Eozoön*, there is a strong *a priori* improbability of such exceedingly minute structures as the "canal-system" of a Foraminiferal test being preserved in rocks so highly crystalline as are the Laurentian limestones.

e. The canals of the so-called "canal-system" are often flat, instead of round, and are commonly unequal in point of size, while it is not unusual to find them running *obliquely* to the calcareous laminæ instead of *transversely*. These considerations would tend to show that the "canal-system" is of inorganic origin.

f. The "proper wall" is not truly tubulated, but is formed of minute parallel fibres of serpentine. It is therefore a purely inorganic structure, and is really of the nature of a vein of fibrous serpentine ("chrysotile").

Some of the above arguments against the organic nature of *Eozoön* are of a general nature, and their weight must necessarily remain largely a matter of individual judgment. Others are of a special character, and deal with matters of observation, as to which there are differences of opinion. The *special* arguments all hinge upon two points—viz., the "canal-system" and the "proper wall"—and with regard to these the following considerations may be indicated: On the view that the "canal-system" is of inorganic origin, it has usually been assumed that it consists of branched fibres of *serpentine* or of some other silicate, developed in the calcareous laminæ. The larger canals are, it is true, commonly filled with serpentine, but it admits of demonstration that the smaller canals are commonly, and in fact usually, occupied simply by *crystalline carbonate of lime*. On this point, the author is able to fully corroborate the observations of Carpenter and Dawson. In the second place, it can be proved that the so-called "proper wall" of *Eozoön* is, as a rule, *calcareous*, and that it cannot, therefore, be regarded as universally of the nature of fibrous serpentine (chrysotile). This can be best shown by acting with acids on thin vertical sections of *Eozoön* along a narrow transverse band, leaving the two ends of the section untouched. When this is done, it is found that along the narrow tract acted upon by the acid, not only have the calcareous laminæ been dissolved out, but the so-called "proper wall" *has at the same time also disappeared*, its composition out of carbonate of lime being thus conclusively proved. In some cases, the "proper wall" does not appear to be wholly destroyed by acids, and in such cases it may be supposed that the tubuli of this structure have been injected with serpentine, and have thus been enabled to resist the action of the solvent. The above observation, at any rate, appears to show conclusively that the so-called "proper wall" cannot be *always* of the nature of a layer or vein of fibrous serpentine (chrysotile), since it is very commonly and quite unquestionably soluble in weak acids. At the same time, true chrysotile veins often intersect masses of *Eozoön*, and it is quite probable that in some instances such veins have been confounded with the peculiar striated selvage to the calcareous laminæ of *Eozoön*, which is really what should be understood as the "proper wall."

Upon the whole, therefore, it would appear that the much-vexed question of the true nature of *Eozoön* is still incapable of receiving its final solution. It is clear that in any endeavour to solve this problem only the *best* specimens—those, namely, which possess the so-called "canal-system" and "proper wall" in a well-preserved state—can be taken into account; since it is one of the most ordinary experiences of palæontologists to find that out of a series of specimens of some quite indubitable fossil—such as a coral—only a very limited number retain their internal structure in a recognisable condition. It is also a reasonable argument that until mineralogists or petrologists are able to point in some unquestionable mineral or rock to a structure strictly comparable with the "canal-system" of *Eozoön*, they are not entitled to assert positively that the latter has a purely inorganic origin. Lastly, some weight must be attached to the argument that though *analogous* structures (banded rocks of various kinds) are known, nothing clearly inorganic has yet been discovered the general structure of which can be regarded as precisely parallel with that of *Eozoön*.

In connection, finally, with the subject of *Eozoön*, it may be noticed that Sir William Dawson has given the name of *Archæosphærinæ* to small spherical masses of serpentine, sometimes single, sometimes united together in small numbers, which he finds in the Laurentian limestones of Canada, and which he states to be surrounded by a tubulated calcareous shell, resembling the "proper wall" of *Eozoön*. He is of opinion that these bodies are either detached chamberlets of *Eozoön*, or that they are independent organisms, allied to *Eozoön*, but of a simpler type.

CHAPTER IX.

PROTOZOA — Continued.

RADIOLARIA.

THE order of the Radiolarians comprises a vast number of Rhizopods, in which *the sarcode-body consists of a central protoplasmic mass, enclosed in a porous, membranous, or chitinous capsule, which is in turn surrounded by a thick layer of sarcode. The intra-capsular sarcode contains a central "nucleus," and the pseudopodia* (fig. 44) *have the form of slender radiating filaments, which rarely anastomose with*

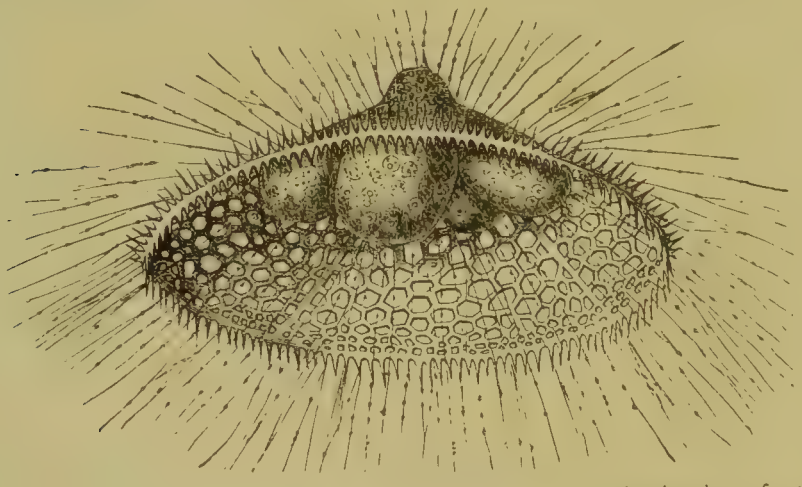


Fig. 44.—*Eucecryphalus Schultzei*, with the pseudopodia extended, showing the perforated siliceous test and the lobed protoplasmic body. (After Köllıker.)

one another. As a rule, the protoplasmic body secretes a radially disposed skeleton composed of silica, of a silicate, or of a horny substance ("*acanthin*").

As regards the *skeleton* of the Radiolarians, some forms (*Thalassicolla*, *Thalassolampe*, *Collozoum*, &c.) are wholly devoid of hard

structures. Moreover, among those types in which a skeleton is developed, there are great differences as regards both the chemical composition and the structure of this. As regards the first of these points, the skeleton is never calcareous, but presents itself under one or other of the following three modifications. In the first place, the skeleton may be composed of pure silica. This is the case in the *Polycystina* (the *Spumellaria* and *Nassellaria* of Haeckel), which constitute the largest and most typical group of Radiolarians. In another series of forms the skeleton is a compound of silica with some organic compound, or is a "silicate of carbon" (Haeckel). This occurs in the entire group of the *Phæodaria*, except in *Dictyocha* and its allies. Lastly, in a third series of forms the skeleton consists of a peculiar organic substance ("acanthin") allied to chitine or horn. The forms in which the skeleton is of this nature are grouped together by Haeckel under the name of *Acantharia*.

As regards the *form* of the skeleton, the most usual type is that of a latticed shell (fig. 45), enclosing the central capsule. In certain Radiolarians, however, the skeleton consists of radially or tangen-

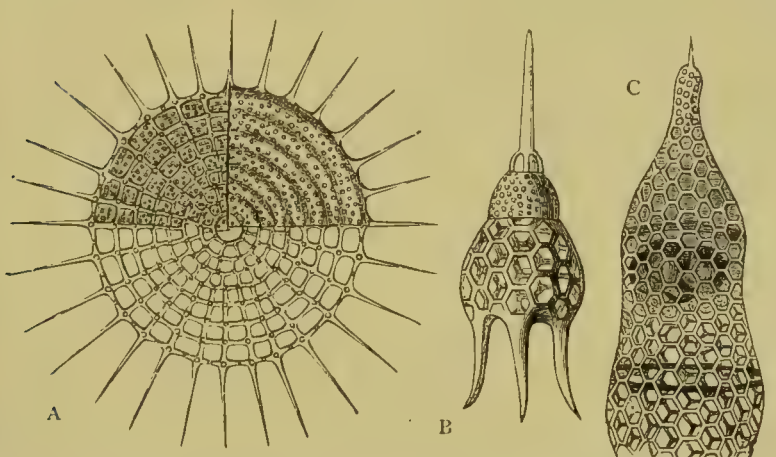


Fig. 45.—Skeletons of *Polycystina*. A, *Stylodictya multispina*; B, *Podocyrtis Schomburgii*; C, *Eucyrtidium lagena*. (After Haeckel.)

tially disposed spicules; or it may have the form of a simple ring, or of a "basal tripod with or without a loose tissue of trabeculæ" (Haeckel). In the *Polycystina* (*Spumellaria* and *Nassellaria*), the siliceous bars of the skeleton are invariably solid, whereas in the *Phæodaria* the parts of the skeleton are always hollow.

As regards their *classification*, Professor Haeckel raises the Radiolarians to the rank of a distinct *class* of the *Protozoa*, and he divides them into the following four legions or sub-classes :—

1. SPUMELLARIA.—Capsular membrane perforated by innumerable fine pores. Fundamental form originally spherical. Skeleton siliceous, or

in some cases absent. No dark pigment-body ("phæodium") in the extra-capsular sarcode.

This division includes forms such as *Thalassicolla* and *Collozoum*, in which the skeleton is wanting, with others having a skeleton of siliceous spicules, and with a large number of the forms usually spoken of as "*Polycystina*" in which the skeleton has the form of a latticed siliceous shell.

2. ACANTHARIA.—Capsular membrane perforated by numerous fine pores. Fundamental form originally spherical. Skeleton composed of "acanthin." No dark pigment-body in the extra-capsular sarcode. This group includes forms such as *Acanthometra* and its allies.

3. NASSELLARIA.—Capsular membrane perforated by a porous area, or by one single large opening divided into numerous very fine pores. Fundamental form originally egg-shaped. Skeleton siliceous. No dark pigment-body ("phæodium") in the extra-capsular sarcode. This group comprises all those "*Polycystina*" which are not included under the head of *Spumellaria*.

4. PHÆODARIA. — Capsular membrane double, perforated by one simple main opening prolonged into a tube, commonly with one or two small accessory openings. Fundamental form originally egg-shaped. A dark pigment-body ("phæodium") is constantly present in the extra-capsular sarcode. The skeleton is siliceous, being usually composed of a compound of silica with some organic substance, but in other instances (*Dictyocha*) consisting of pure silica.

As regards their *distribution in space*, the Radiolarians are exclusively marine, and are found in all seas and at all depths. They are commonly floating organisms, and are often present in enormous numbers, the greatest variety of specific types, however, being found in the warm seas of the tropics. Many Radiolarians are "pelagic," and inhabit the surface-waters of all oceans; others are "abyssal," and are confined to great depths in the sea; while others, again, are "zonarial," and are restricted to particular bathymetrical horizons between the surface and the bottom. Over large areas of the deep sea, principally at depths of from two thousand to over four thousand fathoms, the bottom is found to be covered with extensive deposits of "Radiolarian ooze." The deposit so called is a siliceous mud, with little calcareous matter, which is composed more or less largely of the siliceous tests of various Radiolarians. The skeletons of Radiolarians are, however, also present, in smaller or greater numbers, in many of the marine deposits which are formed at comparatively limited depths.

As regards their *distribution in time*, the Radiolarians are abundantly represented by fossil forms, and are now known to have a high antiquity. Owing, however, to the vast number of forms included in the *Radiolaria*, and the great complexity of their classification, the study of the fossil types can hardly be undertaken except by a specialist. For these reasons, nothing further will be here attempted than merely to give a brief outline of the more important facts relating to the past history of the *Radiolaria*. The student

desirous of fuller information, or anxious to study the fauna of any particular Radiolarian deposit, will of necessity consult the works of Ehrenberg, Rüst, Haeckel, and others, who have specially devoted themselves to the study of these minute organisms.

As regards the past history of the great groups of the Radiolarians, the *Acantharia*, in which the skeleton is composed of "acanthin," are wholly unknown in the fossil condition. This is likewise the case with the group of the *Phæodaria*—in which the skeleton is composed of silicate of carbon—with the single exception of the small group represented by *Dictyocha* and its allies, in which the skeleton is purely siliceous. In *Dictyocha* (fig. 46, *d*), the skeleton is composed of irregular bars of flint united into a loose network with wide meshes. The genus begins in the Upper Chalk, and is represented in Tertiary deposits and in recent seas.

With the above-noted exception, all the known fossil Radiolarians belong to the group of the so-called "*Polycystina*," comprised in the two divisions defined by Haeckel under the names *Spumellaria* and *Nassellaria*. In all of these forms the skeleton is purely siliceous, and it usually has the form of a porous latticed shell, the precise shape of which varies in different types.

Until recently, Radiolarians had only been detected in the fossil condition in deposits of Kainozoic and Mesozoic Age; and our knowledge of Palæozoic types of Radiolarians is still very incomplete. According to Haeckel, however, Dr Rüst (whose researches on this subject are still unpublished) has discovered various types of *Polycystina*, "of very simple form and primitive structure," in rocks as old as the Silurian, or even the Cambrian. The remains of Radiolarians have also been indicated as occurring in the Carboniferous Limestone of England, but the true nature of these has not been clearly established.[1]

Radiolarian remains have now been discovered in all the great Mesozoic systems. From the Jurassic system, in particular, numerous fossil *Polycystina* have been described by Zittel, Dunikowski, and Rüst. A noticeable Jurassic genus is *Cœnosphæra*, which is also found in the Chalk, in the Miocene marls of Barbados, and in recent seas, and which has relationships with *Collosphæra*. Many of the Jurassic Radiolarians occur in jasper, flint, or chert; but they are especially abundant in what have been termed "Radiolarian quartzes." These are cryptocrystalline quartzites or hard siliceous rocks, which are composed "for the most part of the closely compacted shells of *Spumellaria* and *Nassellaria*" (Haeckel). The

[1] Considerable portions of the Carboniferous Limestone of Britain are occasionally partially composed of the minute calcareous spheres which have been described under the name of "*Calcisphæræ*." These enigmatical bodies are now composed of carbonate of lime; but it has been conjectured that they were originally siliceous, and that they are really referable to the *Radiolaria*.

jaspers with Radiolarians are considered by Haeckel as of the nature of true "silicified deep-sea Radiolarian ooze." Many forms of Radiolarians have also been yielded by the so-called "Radiolarian coprolites" of the Lias of Hanover. These are "roundish or cylindrical bodies, which may attain the size of a goose-egg; they probably originated from Fish or Cephalopods, which had fed upon Crustacea, Pteropoda, and similar pelagic organisms, whose stomachs were already full of Radiolarian skeletons" (Haeckel).

The Radiolarians which have hitherto been discovered in the Cretaceous rocks are few in number, but Zittel has described several

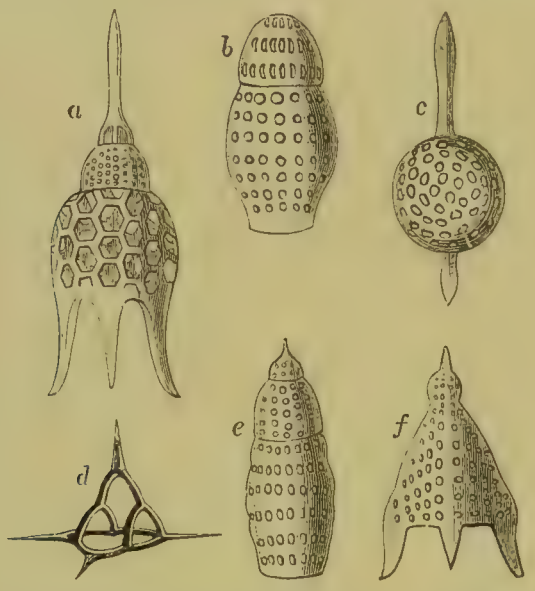


Fig. 46.—Types of Polycystina. *a*, *Podocyrtis Schomburgii*; *b*, *Dictyomitra Montgolfieri*; *c*, *Haliomma dixiphos*; *d*, *Dictyocha Messanensis*; *e*, *Eucyrtidium elegans*; *f*, *Lychnocanium lucerna*. *d* is living, and is after Haeckel; the remaining are Tertiary, and are after Ehrenberg. All the figures are greatly enlarged.

species from the Upper Chalk of Germany. The Cretaceous genera *Dictyomitra* (fig. 46, *b*) and *Stylodictya* (fig. 45, A) are represented in both Tertiary and recent seas.

In formations belonging to the Tertiary period, Radiolarians are found in vast abundance in certain deposits (marls and clays), which may be regarded as "fossil Radiolarian oozes." These Tertiary Radiolarian clays and marls appear to be very widely distributed, but the most famous of these deposits is the Polycystine Marl of Barbados, the age of which is Miocene. The so-called "Barbados earth" is a friable, earthy or chalky marl, which rises to heights of over 1000 feet above the level of the sea, and is more or less extensively composed of the shells of Radiolarians, with a variable proportion of the calcareous tests of the *Foraminifera*. According

to Haeckel, the number of species of Radiolarians in the Barbados earth is not less than four hundred, and is probably more than five hundred. This eminent authority regards the Barbados earth as a deep-sea deposit, and states that very many of the Barbados Radiolarians "are to-day extant and unchanged in the Radiolarian ooze of the deep Pacific Ocean."

Very similar to the Barbados earth is the Polycystine marl or "tripoli" of Sicily, Calabria, Greece, and Northern Africa, the age of which is also Miocene. Another deposit of the same nature is the tripoli or Radiolarian clay of the Nicobar Islands, which rises to elevations of about 2000 feet above the level of the sea, and is probably of Miocene or Oligocene age.

Of the more common Tertiary genera of Radiolarians, *Haliomma* (fig. 46, *c*), *Heliodiscus*, *Actinomma*, and *Didymocyrtis* belong to a group of forms in which the skeleton consists of two, three, or more porous spherical shells, included concentrically within one another, the smaller within the larger, and united by radial bars. In other cases, as in the genera *Podocyrtis* (fig. 46, *a*), *Eucyrtidium* (fig. 45, c), *Lychnocanium* (fig. 46, *f*), and *Dictyomitra*, the skeleton has the form of a latticed shell, which may be undivided, or is partially marked off into two or more compartments by transverse constrictions. The two poles of the shell in these cases are quite unlike each other, and the membranous capsule of the living animal is included within the closed apical pole. In other cases, again, the skeleton consists of a flat, or lenticular and biconvex plate, which is sometimes double, and has a more or less complex internal structure. This type of skeleton is found in such genera as *Astromma*, *Trematodiscus*, *Rhopalastrum*, *Stephanastrum*, and *Stylodictya* (fig. 45, A).

LITERATURE.

FORAMINIFERA.

1. "Introduction to the Study of the Foraminifera." 'Ray Society.' 1862. W. B. Carpenter.
2. "Report on the Foraminifera." 'Rep. on the Sci. Results of the Voyage of H.M.S. Challenger,' vol. ix. 1884. Henry B. Brady.
3. "Carboniferous and Permian Foraminifera" (with a general Introduction). 'Monographs of the Palæontographical Society,' 1876. H. B. Brady.
4. "Handbuch der Palæontologie," vol. i. pp. 61-114, 1876. Zittel.
5. "Mikrogeologie." Ehrenberg. 1854.
6. "Foraminifères Fossiles du Bassin Tertiaire de Vienne." D'Orbigny.
7. "Entwurf einer systematischen Zusammenstellung der Foraminiferen." 'Sitzungsber. d. k. Akad. Wiss. Wien,' 1861. Reuss.
8. "Monograph of the Foraminifera of the Crag," 1868. Rupert Jones, Parker, and Brady.

9. "Mémoires sur les Foraminifères du Lias." 'Mém. de l'Acad. Impériale de Metz,' 1858-1866. Terquem.

EOZOÖN.

1. "The Dawn of Life." J. W. Dawson. 1876.
2. "On the Occurrence of Organic Remains in the Laurentian Rocks of Canada." Sir W. E. Logan. 'Quart. Journ. Geol. Soc.,' xxi. 45-50. 1865.
3. "On the Structure of Certain Organic Remains in the Laurentian Limestones of Canada." J. W. Dawson. 'Quart. Journ. Geol. Soc.,' xxi. 51-59. 1865.
4. "Additional Note on the Structure and Affinities of Eozoön Canadense." W. B. Carpenter. 'Quart. Journ. Geol. Soc.,' xxi. 59-66. 1865.
5. "Supplemental Note on the Structure and Affinities of Eozoön Canadense." W. B. Carpenter. 'Quart. Journ. Geol. Soc.,' xxii. 219-228. 1866.
6. "On the So-called Eozoönal Rock." King & Rowney. 'Quart. Journ. Geol. Soc.,' xxii. 185-218. 1866.
7. "Der Bau des Eozoön Canadense." 'Palæontographica,' vol. xxv. 1878. Möbius.
8. "Möbius on Eozoön Canadense." 'Amer. Journ. Sci. and Arts,' 1879. Dawson.
9. "New Facts relating to Eozoön Canadense." 'Geological Magazine,' 1888. Dawson.
10. "Specimens of Eozoön Canadense, and their Geological and other Relations." Dawson. 1888.

RADIOLARIA.

1. "Report on the Radiolaria." 'Rep. on the Sci. Results of the Voyage of H.M.S. Challenger,' vol. xviii. (two volumes of text and one of Plates). 1887. Haeckel.
2. "Die Radiolarien." 1862. Haeckel.
3. "Ueber die Thalassicollen, Polycystinen, und Acanthometren des Mittelmeeres." 'Abhandl. d. k. Akad. d. Wiss. Berlin.' 1858. Johannes Müller.
4. "Mikrogeologie." 1854. Ehrenberg.
5. "Mikrogeologische Studien über das kleinste Leben der Meeres-Tiefgründe aller Zonen." 'Abhandl. d. k. Akad. d. Wiss. Berlin. 1872. Ehrenberg.
6. "Fortsetzung der Mikrogeologische Studien." (Polycystinen-Mergel von Barbados). 'Abhandl. d. k. Akad. d. Wiss. Berlin.' 1875. Ehrenberg.
7. "Ueber fossile Radiolarien der oberen Kreide." 'Zeitschr. d. deutsch. Geol. Gesellsch.,' 1876. Zittel.
8. "Handbuch der Palæontologie." 1877. Zittel.
9. "Die Radiolarien-Fauna der Tripoli von Grotte." 'Palæontographica,' vol. xxvi., 1880. Stöhr.
10. "Die Spongien, Radiolarien, und Foraminiferen der Unter-Liassischen Schichten von Schafberg bei Salzburg." Denkschr. d. k. Akad. d. Wiss. Wien.' 1882. Dunikowski.
11. "Beiträge zur Kenntniss der fossilen Radiolarien aus Gesteinen des Jura." 'Palæontographica,' 1885. Rüst.

CHAPTER X.

SUB-KINGDOM II.—PORIFERA.

UNDER the name of *Porifera* are included all those singular organisms which are commonly known as Sponges. Originally regarded as being of a vegetable nature, the Sponges are now universally admitted to be animals; though naturalists are not yet in absolute agreement as to the precise position in the animal kingdom which ought to be assigned to them. Owing to the close likeness of some of the cell-elements of the Sponges to certain of the *Protozoa*, the entire group has been often referred to this latter sub-kingdom. Thus, some of the cells of a sponge are morphologically identical with the *Amœbæ*, while others present the closest possible resemblance to the Flagellated *Infusoria*. Hence, a sponge has often been regarded as being a kind of colony, the units of which are morphologically Protozoans. Naturalists are, however, now agreed as to the removal of the Sponges from the *Protozoa;* and they are by many authorities regarded as forming the lowest division of the Zoophytes (*Cœlenterata*). Other authorities consider that the Sponges represent a distinct morphological type, intermediate between the *Protozoa* and the *Cœlenterata*, and that they are therefore entitled to take rank as a separate sub-kingdom, to which the name of *Porifera* has been given. In the present state of our knowledge, this view seems to be the one which is attended with the fewest difficulties, and it will therefore be followed here.

The Sponges may be defined as *multicellular organisms of variable shape, the cells of which are typically disposed to form an outer membrane, an inner membrane, and an intermediate stratum; and which are traversed by canals, which open on the surface, and which are more or less extensively lined by flagellate cells. In most cases the cellular aggregate is supported by a framework of horny fibres, or of flinty or calcareous spicules. A definite mouth and stomach are wanting, and a nervous system is not known with certainty to be developed.*

The entire aggregate of cells which constitutes a sponge is so

arranged as to be traversed by a series of canals, which convey water in and out of the organism, and which are thus connected with respiration and the procuring of food. Looking at the skeleton of a dried sponge, the most obvious sign of the existence of this "aquiferous system" is the presence of one or more large superficial openings, together with a great number of much smaller apertures (fig. 47,

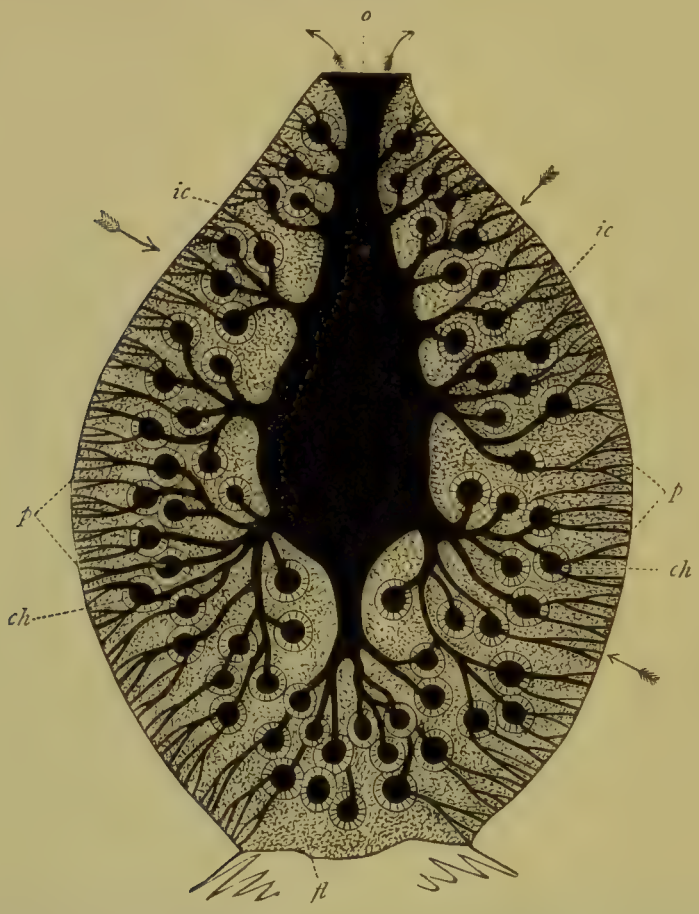


Fig. 47.—Diagrammatic representation of the structure of a simple Sponge, as seen when cut in half vertically. The general "sponge-flesh" is lightly shaded (*fl*); the canal-system is black, and the arrows show the course of the water-currents. *p p*, "Pores," opening into "inhalant canals," which conduct to the "ciliated chambers" (*ch*). From these chambers proceed the larger "exhalant canals" (*ic*), which open into a general central space or "cloaca." This space terminates on the surface by a single large opening or "osculum" (*o*), which serves for the exit of the water. (After Haeckel.)

p p). These latter are termed the "pores," and though permanently present in the skeleton, they are only temporarily present in the soft parts, being produced afresh, when required, as openings between the sponge-bells of the ectodermal layer. The "pores" (fig. 47, *p p*) open directly, or through the intervention of more or less extensive subdermal cavities, into a series of canals, which ramify in

every direction through the sponge, and which are called "inhalant canals," as it is through these that the water is conveyed to the interior of the sponge. The "inhalant canals" ultimately open into a second series of canals, which converge to form one or more large tubes which open on the surface by a corresponding number of large openings. These large tubes (fig. 47, *ic*) carry the water out of the organism again, and they are hence called "exhalant canals"; while their surface-openings are known as the "oscula." The "oscula," though capable of being temporarily closed, are permanent, and are often placed on chimney-like elevations. If there should be but one osculum, it is placed at the apex of the sponge (fig. 47, *o*), while the pores occupy the general external surface. What is commonly called a "sponge" may consist of only a single excretory opening or "osculum," together with the "pores" belonging to this (fig. 47); or it may consist of a larger or smaller number of such "oscula," each with its proper complement of "pores." In the latter case, each osculum, with its accompanying pores, constitutes a "person," and the entire organism is known as a "sponge-stock."

In a living sponge, in its active condition, a circulation of water is kept up throughout the organism by means of this system of canals. The water is admitted from the exterior by the pores, and is driven through the deeper parts of the sponge by means of flagellate cells, which line a series of globular chambers developed between the inhalant and the exhalant canals (fig. 47, *ch*). From these "flagellated chambers" the water is driven into the exhalant canals, and finally escapes again by the osculum or oscula. In this way, the separate sponge-cells are enabled to carry on their nutritive and respiratory processes.

In a few sponges (the *Myxospongiæ* of Haeckel) there is no skeleton, and the above description would, therefore, fully express the general structure of the organism. In the vast majority of sponges, however, the soft cellular body is supported by more or less extensively developed hard structures, which collectively constitute the *skeleton*. The nature of the skeleton varies greatly in different forms, and these variations have been largely made use of in the identification and classification of the Sponges. Speaking generally, the skeleton has the form of a more or less coherent framework, composed either of horny fibres, or of needles of mineral matter, or of both these elements in combination. The different modifications of the skeleton will be more particularly spoken of in dealing with the different groups of sponges. It will be sufficient to point out here that, apart from modifications in the *form* of the skeletal elements, there are the following four principal types of skeleton among the Sponges:—

1. In certain sponges (such as the Common Bath Sponges) the skeleton (fig. 48, A) is wholly composed of netted horny fibres, without proper "spicules." The substance composing the fibres in such

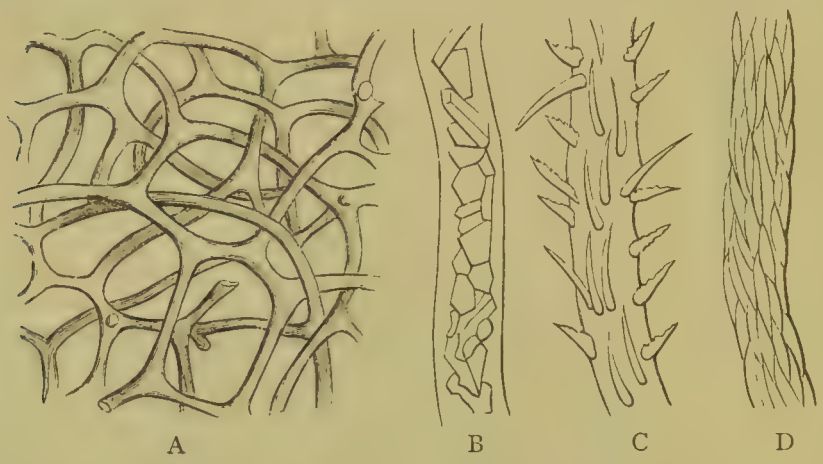


Fig. 48.—Forms of the skeleton in the fibrous Sponges. A, Horny, non-spiculate skeleton of the Bath Sponge, enlarged about fifty times; B, Horny fibre cored with sand-grains; C, Horny fibre with projecting siliceous spicules ("Echinonematous" Sponge); D, Fibre in which the spongin has been more or less completely replaced by siliceous spicules ("Holorhaphidote" Sponge). B, C, and D are greatly enlarged, and are after Carter.

types is allied to horn, but not precisely of the same nature, and it is known as "spongin" or "keratode."

2. In another group of sponges, including most of the commoner forms, the skeleton is more or less extensively composed of siliceous

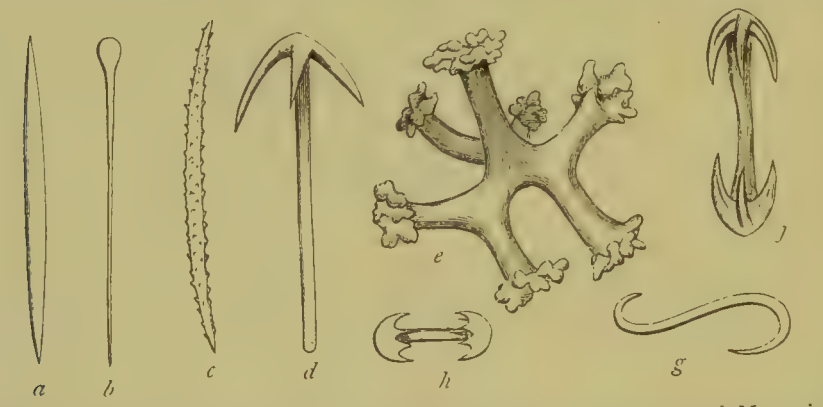


Fig. 49.—Spicules of Sponges. *a*, Monactinellid skeleton-spicule of *Reniera*; *b*, Monactinellid spicule of *Cliona*; *c*, Monactinellid spicule of *Spongilla*; *d*, Tetractinellid skeleton-spicule of *Geodia*; *e*, Skeleton-spicule of a Lithistid Sponge (*Jerea*); *f*, Flesh-spicule of *Cribella*; *g*, Flesh-spicule of *Esperia*; *h*, Flesh-spicule of *Hyalonema*. All the figures are greatly enlarged. (After Schmidt, Vosmaer, Zittel, &c.)

needles or "spicula," of various forms (fig. 49). These spicules may be embedded in various ways in a reticulated fibrous skeleton of spongin (fig. 48, C); or the horny material may be greatly reduced,

so that the skeleton-fibre consists essentially of minute flinty needles (fig. 48, D).

3. In a third group of sponges, the skeleton is destitute of horny matter, and consists wholly of siliceous spicules, which may be fused with one another into a continuous framework, or may be so interlocked by their ends as to produce practical rigidity, or may be simply held in position by the fleshy substance of the sponge. In both this group and the preceding, in addition to the spicules of the proper skeleton, there are generally developed in the mesoderm numerous still more minute microscopic needles of flint, which are known as "flesh-spicules."

4. Lastly, there is a group of sponges in which the skeleton is wholly made up of spicules of carbonate of lime.

In all sponges which possess hard structures of flint or lime, the "spicules" consist, each, of concentric layers of mineral matter deposited round a central fibre of organic matter which occupies an "axial canal" in the spicule. In the *Calcispongiæ* each spicule may be regarded as essentially a single crystal of carbonate of lime. In the ordinary recent siliceous Sponges, on the other hand, the spicules are composed of colloidal silica, which is as clear as glass, wholly non-crystalline, and entirely unaffected by polarised light between crossed Nicols. The silica of recent sponge-spicules is also soluble in hot solutions of caustic potash.

As regards the *distribution* of the Sponges *in space*, the great majority are marine, but representatives of the *Spongillidæ* are found in fresh waters in all the great continental regions except Australia. Of the marine Sponges, the *Calcispongiæ* and *Ceratospongiæ* are principally inhabitants of shallow water. On the other hand, the Hexactinellid Sponges are mostly found in deeper water, the majority living at depths of from 100 to 2500 fathoms. The Lithistid Sponges, on the contrary, are found in comparatively shallow water, being most abundant between depths of 10 to 150 fathoms.

In connection with the subject of the *distribution in time* of the Sponges, it is necessary to briefly consider the different modes in which the skeleton of the Sponges may be preserved in the fossil condition. Taking first the Sponges which secrete a siliceous skeleton, it has been pointed out above that the silica of the spicules or spicular network of these, in the *recent* condition, is colloidal and non-crystalline, glassy, and entirely unaffected by polarised light. Though unaffected by acids, the spicules undergo solution in hot caustic potash, and there is reason to know that they readily become changed, or even dissolved, under certain natural conditions which it is difficult or impossible to imitate in the laboratory. While the above is the condition of the siliceous spicules in recent Sponges, these structures in fossil Sponges have, as a rule, undergone more or less change during the process of fossilisation, the following being the principal forms of alteration which have been observed.

(*a.*) The silica of the spicules may be changed into an amorphous

condition. The alteration is in this case but slight, since the silica is still in the colloidal state, and the principal change that has occurred is that the spicules have lost their original glassy aspect, and have become porcellanous and milky-white when viewed by reflected light.

(*b.*) The silica of the spicules may have become cryptocrystalline or crystalline. In this form of alteration, the original colloidal silica of the spicules has become changed into chalcedony or quartz, and the spicules now exhibit with polarised light the same colour-changes as are shown by the above minerals.

(*c.*) In a great many cases among fossil Sponges, the original flinty skeleton has undergone more or less complete solution during fossilisation, the Sponge being now represented only by hollow casts of the original skeleton in the matrix of the enclosing rock. In the case of calcareous organisms it has long been well known to palæontologists that the skeleton very commonly undergoes solution, leaving nothing but a hollow mould or impression in the rock to mark its former existence. Silica being a much more stable substance than carbonate of lime, it used to be supposed that an originally flinty skeleton would not be liable to undergo a similar solution. It has, however, been conclusively shown by Zittel, Sollas, and Hinde, that this supposed stability of organic silica is largely imaginary. According to the last-named observer, "it may be accepted as proved that silica in the colloid state, in which it occurs in the skeleton of recent siliceous Sponges, and also in the original condition of fossil Sponges, is extremely liable to chemical changes, and that it is only when it is in the condition of chalcedony, or is crystalline, that it can be regarded as stable. The changes in the siliceous skeletons of fossil Sponges, mentioned above, show the tendency of the silica to pass from the unstable colloid to the stable chalcedonic or crystalline condition. Under favourable conditions this chemical change has taken place without destroying the form of the spicular skeleton, but in other circumstances the colloid silica of the skeleton has been wholly dissolved away, and redeposited, usually in the chalcedonic condition, so as to form solid beds of chert and bands of nodular flints."

(*d.*) In the cases just spoken of, the original siliceous skeleton of the Sponge has undergone solution, and there is left in the rock a hollow mould of the skeleton, this mould being commonly so accurate as to preserve with fidelity the form of the component spicules of the skeleton. Very usually, however, the mould thus formed becomes ultimately completely filled up with some mineral substance deposited from the water which percolates through the rock; the result being the formation of a "pseudomorph" of the original Sponge, or, in other words, a body which has the exact form, and may even have the microscopic structure, of the original Sponge, but which consists of some secondary substance which has taken the place of the original skeleton. The substance which has in this way replaced the original Sponge is most commonly crystalline calcite, but peroxide of iron is likewise often the replacing material, or, less commonly, iron-pyrites or glauconite; while in some cases it would appear that the replacing substance has been chalcedonic silica. It only needs to be added in this connection that the changes above spoken of do not necessarily affect an entire Sponge, but that specimens often occur in which a portion of the skeleton has been fossilised in one way, while another part may have been preserved in a different manner.

The *Calcispongiæ* do not, as a rule, undergo fundamental alteration, as regards their skeletal structures, during fossilisation. In some late

deposits, the spicules of Calcareous Sponges are found in a condition not recognisably different from that of recent examples. As a rule, "the spicular fibres of fossil Calcisponges retain their original structure of carbonate of lime, though the form of the component spicules has to a large extent disappeared, and the fibres are now either of crystalline grains of calcite or show a finely radiate prismatic structure" (Hinde). In certain cases, however, the calcareous skeleton of a Calcisponge may be found to be replaced, as occurs commonly in the case of Corals and other calcareous organisms, by chalcedonic silica. Such "silicified" specimens have necessarily undergone an entire destruction of the minute structure of the skeleton, though the *form* of the skeleton may be perfectly well preserved.

As regards their general *geological distribution*, the Sponges are very largely represented in past time, and have a very high antiquity. The two recent groups of the *Myxospongiæ* and *Ceratospongiæ*, being devoid of hard parts or having only a horny skeleton, are unknown in the fossil condition, though doubtful examples of the latter have been brought forward. The Sponges with a skeleton of siliceous spicules are known to occur in deposits as ancient as the Cambrian, the oldest Sponge at present known being the *Protospongia fenestrata* (fig. 50) of the Menevian Slates of St David's, South Wales. In strata of Ordovician age the remains of Sponges are not very uncommon, the groups of the *Lithistidæ* and *Hexactinellidæ* being both represented, the former by types like *Hindia*, and the latter by *Hyalostelia*, *Receptaculites*, and *Ischadites*. In the Silurian deposits the same groups of Sponges are well represented by forms such as *Aulocopium*, *Astylospongia*, and *Dictyophyton*; while the group of the Monactinellid Sponges is represented by the genus *Climacospongia*. If we except the aberrant group of the *Receptaculitidæ*, the Devonian system has, so far, proved to be singularly barren of Sponge remains, though a few types (*Astræospongia*, *Dictyophyton*, &c.) have been detected in strata of this age. On the other hand, the seas of the Carboniferous period were tenanted by a vast abundance of Sponges, belonging to few generic types—so far as yet known—but representing the distinct groups of the *Monactinellidæ*, *Tetractinellidæ*, *Lithistidæ*, *Hexactinellidæ*, and

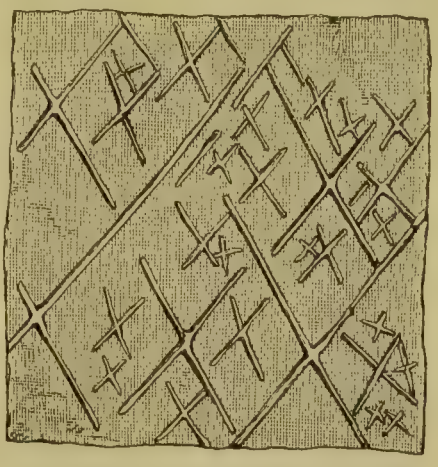


Fig. 50.—Part of the spicular mesh of *Protospongia fenestrata*, enlarged five diameters, from the Menevian strata of South Wales. The spicules are slightly distorted by cleavage. (After Hinde.)

Heteractinellidæ. So great was the profusion of Sponge-life during Carboniferous times that thick beds of chert—as conclusively demonstrated by Hinde—were formed by the gradual accumulation of siliceous spicules on the floor of the sea. These siliceous sponge-beds are largely developed in the Carboniferous limestone and Yoredale beds of the North of England, Wales, and Ireland, and may reach a thickness of more than fifty feet [in Ireland, a maximum thickness of over 300 feet of these chert-beds has been observed]. The highest Palæozoic deposits—viz., the Permian—have hitherto yielded few or no unequivocal remains of Sponges.

Coming to the Mesozoic deposits, the Trias has not yielded a large number of Sponges, and the great majority of the known forms of this period belong to the *Calcispongiæ*, and are referable to the extinct group of the *Pharetrones*. On the other hand, an enormous number of Sponges are known to occur in strata of Jurassic age, almost all the hitherto recognised types of this period belonging to the three groups of the *Lithistidæ*, *Hexactinellidæ*, and *Pharetrones* (*Calcispongiæ*). At the summit of the Jurassic system (in the Purbeck beds) we also meet with the first undoubted representative of the fresh-water genus *Spongilla*. In the Cretaceous system, and especially in its upper division, Sponges also occur in vast numbers, the three groups above mentioned being those most largely represented. It is noticeable, however, that the aberrant Calcisponges which form the group of the *Pharetrones* diminish in numbers towards the close of the Cretaceous period; while the groups of the *Monactinellidæ* and *Tetractinellidæ* have a fair representation. In parts of the Cretaceous system, and particularly in the Lower and Upper Greensand, occur beds of siliceous rock, which have been shown by Hinde to have been formed by the accumulation of the microscopic spicules of various types of Sponges. In some cases, these spicules are loosely compacted together, and give rise to a porous siliceous rock. More commonly, however, the spicules have undergone partial solution in sea-water, and the dissolved silica thus obtained has been subsequently redeposited, and has formed a siliceous cement which has bound together the undissolved spicules in a general cherty matrix. In such cases, the true nature of the rock can only be recognised by an examination of thin sections (fig. 51) under the microscope.

There is, further, every reason to believe that the nodular flints which form such a striking feature in the White Chalk have been in reality produced by the solution of the skeletons of flinty Sponges and other siliceous organisms, and the subsequent redeposition of the silica thus obtained in a solid form. It is well known, namely, that the siliceous Sponges of the White Chalk have usually had their original siliceous skeleton more or less wholly dissolved out,

the original skeleton being now represented either by empty casts in the rock or by pseudomorphs of lime, peroxide of iron, or iron-pyrites. The general freedom of the body of the White Chalk from silica can thus be readily explained on the ground that the siliceous organisms which it, to begin with, contained, underwent a more or less complete solution. The dissolved silica thus obtained must, however, have been from time to time redeposited in a solid form, thus giving rise to the nodules of flint which are so largely disseminated through parts of the White Chalk. On this view, the silica of the Chalk-flints had an organic origin, though deposited from solution in sea-water. On this view, it is also possible to account for the fact that the silica, in course of redeposition, should not only have accumulated in a nodular form round any foreign bodies which may have been lying on the sea-bottom at the time, but should also have commonly penetrated into the internal cavities of organic bodies, or should even have given rise to tabular masses or to actual veins.



Fig. 51.—Section of chert from the Upper Greensand, showing numerous sponge-spicules embedded in a chalcedonic matrix, enlarged forty diameters. (After Hinde.)

In deposits of Tertiary age, finally, remains of Sponges have hitherto been detected in much smaller numbers than in the preceding Mesozoic strata. The great group of the *Pharetrones* among the *Calcispongiæ* seems to have become extinct with the close of the Cretaceous period, and the Hexactinellids and Lithistids are for the most part but poorly represented. In the Miocene strata of Algeria, however, Pomel has described an abundant fauna of Hexactinellid and Lithistid Sponges.

CHAPTER XI.

PORIFERA—Continued.

Classification and Principal Groups of the Sponges.

There is, perhaps, no single group of the animal kingdom in which it has proved so difficult to establish a natural classification, as has been found to be the case with the Sponges. Even at the present day there is no extant classification which can be regarded as final. It is, however, now generally admitted that the calcareous Sponges are so far separated from all the other groups of Sponges as to properly constitute a distinct *class* of Sponges. The non-calcareous Sponges may be grouped together in a second class under the name of *Plethospongiæ*, proposed for them by Professor Sollas. As regards the ordinal divisions of the *Plethospongiæ*, the grouping followed by Professor Zittel may be adopted, with some modification, and the general classification of the Sponges is thus expressed in the following table :—

SUB-KINGDOM PORIFERA.

Class I. Plethospongiæ (Sollas).

Order 1. Myxospongiæ (*Halisarca*).
„ 2. Ceratospongiæ (*Euspongia*).
„ 3. Monactinellidæ (*Halichondria*, &c.)
„ 4. Tetractinellidæ (*Geodia*, *Tethya*, &c.)
„ 5. Lithistidæ (*Discodermia*, &c.)
„ 6. Hexactinellidæ (*Holtenia*, &c.)
„ 7. Octactinellidæ (*Astræospongia*).
„ 8. Heteractinellidæ (*Asteractinella*, &c.)

[The last six of the above-mentioned orders are regarded by Hinde as sub-orders, and are included in the single order *Silicispongiæ*.]

Class II. Calcispongiæ.

Family 1. Ascones (*Ascetta*, &c.)
„ 2. Leucones (*Leucandra*, &c.)
„ 3. Sycones (*Grantia*).
„ 4. Pharetrones (*Corynella*, &c.)

Class I. Plethospongiæ.

The Sponges included in this class are occasionally destitute of hard structures, but the great majority possess a skeleton, which may be composed of horny fibres alone, or of siliceous spicules alone, or which is formed by a combination of these two sets of structures. In no case is the skeleton composed of carbonate of lime.

Order 1. Myxospongiæ.—The Sponges of this order are entirely destitute of skeletal structures, or, at most, possess a few scattered siliceous spicules. The type-genus is *Halisarca*, comprising a number of soft fleshy sponges, widely distributed in recent seas, which form crusts upon submarine objects. No example of this order, as might be expected from the soft nature of the organism, is known as occurring in the fossil condition.

Order 2. Ceratospongiæ.—In this group of Sponges, the skeleton is composed of the horny substance known as "spongin," and there are either no proper spicules, or in some cases a few siliceous spicules may be scattered in the mesoderm. The horny fibre of the skeleton forms a close reticulation or network (fig. 48, A), and can be shown to consist of a delicate axial thread of organic matter surrounded by a laminated horny sheath. In many cases, the horny fibre includes numerous sand-grains or other foreign bodies in its interior (fig. 48, B), these being taken in at the free-growing ends of the fibres, to which they form a kind of core, replacing the soft organic axis which in some cases is alone present. The type of this order is the recent genus *Euspongia*, comprising the Turkey Sponges of commerce. No undoubted fossil representatives of the *Ceratospongiæ* have been as yet detected in the fossil condition, the cylindrical antler-shaped bodies from the Cretaceous rocks of Germany, which Geinitz described under the name of *Spongites*, being of an altogether problematical nature.

Order 3. Monactinellidæ.—This order comprises an extensive series of Sponges characterised by the possession of a skeleton which is typically composed of horny fibres with included spicules of flint. The spicules vary much in form, but are always uniaxial, being most commonly fusiform, pin-shaped, or bow-shaped (fig. 49, *a*, *b*, *c*, and fig. 52). In recent Monactinellids the proportion borne by the spicules to the horny fibre is very variable, and in some types the skeleton consists almost wholly of uniaxial spicules without any, or with

very little, horny connecting-substance (fig. 48, D). In addition to the proper skeleton-spicules, which are usually connected by a horny fibre, there are developed in the mesoderm more or less numerous disconnected, uniaxial, siliceous needles or "flesh-spicules."

The order of the *Monactinellidæ* is represented by a very large number of existing marine Sponges, as well as by the fresh-water group of the *Spongillidæ*. Owing to the nature of the hard structures in this order, the entire skeleton does not readily admit of preservation, and most of the known fossil forms are therefore repre-

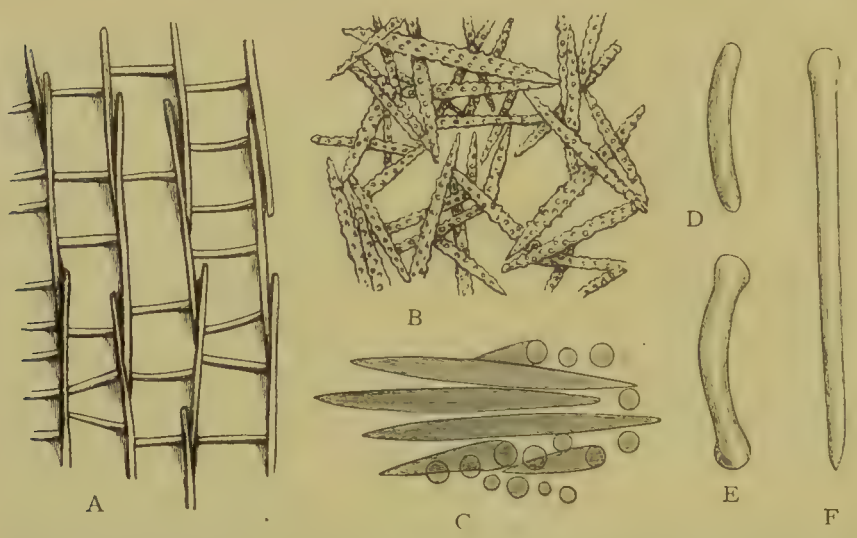


Fig. 52.—Fossil Monactinellid Sponges. A, Part of the spicular network of *Climacospongia radiata*, Silurian, Tennessee, enlarged twelve times; B, Part of the spicular network of *Acanthoraphis intertextus*, Chalk, Kent, enlarged ten times; C, Spicules of *Spongilla Purbeckensis*, as shown in a thin slice of chert from the Purbeck formation, enlarged; D, Spicule of *Reniera gracilis*, Carboniferous, Yorkshire, enlarged sixty times; E, Spicule of *Reniera clavata*, Carboniferous, Yorkshire, enlarged sixty times; F, Spicule of *Axinella paxillus*, Carboniferous, Lancashire, enlarged thirty times. (C is after John Young, and the remaining figures are after Hinde.)

sented by mere fragments or by detached spicules. The record of the distribution of the Monactinellid Sponges in past time is, therefore, necessarily a very imperfect one. The oldest types which have been determined with any certainty occur in the Silurian deposits, in which are found the large uniaxial spicules upon which Hinde has founded the genus *Atractosella*. Of the same age is the genus *Climacospongia* (fig. 52, A), in which the skeleton is composed of elongated acerate spicules arranged in a ladder-like manner. Certain tubular borings in Silurian shells have also been referred to the operations of a Sponge (*Vioa prisca*), supposed to be related to the living boring Sponges (*Cliona*), but the nature of these is very doubtful. On the other hand, fossil shells pierced by borings in all respects similar to those produced by the recent *Clionæ* are not uncommon in Secondary and Tertiary deposits. In the Devonian rocks, Monac-

tinellid Sponges are almost unknown, but strata of this age in Belgium have yielded remains on which the genus *Lasiocladia* has been founded. In the Carboniferous system, on the other hand, particularly in some of the chert-beds associated with the Mountain Limestone and Yoredale series, the remains of Monactinellid Sponges are comparatively abundant. The best known types of this age are *Reniera* and *Axinella*, the former represented by cylindrical spicules (fig. 52, D and E), and the latter by pin-shaped spicules (fig. 52, F). In the genus *Haplistion* more or less complete specimens have been found, showing that the sponge possessed a fibrous skeleton composed of minute, straight, or curved, acerate spicules.

In the Permian rocks no certain remains of Monactinellid Sponges are known, the *Spongillopsis* of Geinitz being apparently inorganic; and the Trias has also yielded so far no traces of this group. In the Jurassic system also, vast as is the number of known Sponges belonging to other orders, no type of the Monactinellids has hitherto been recognised till the very summit of the formation is reached. In the Purbeck beds, however, in chert containing the remains of the fresh-water *Chara*, are found numerous spicules belonging to a fresh-water Sponge, to which the name of *Spongilla Purbeckensis* has been given (fig. 52, C). In the Cretaceous system, likewise, the remains of Monactinellids are very rare, but the Upper Chalk has yielded shells bored by species of *Cliona*, and also the skeleton of the genus *Acanthoraphis* (fig. 52, B), in which the spicules are fusiform and minutely tuberculate. In the Tertiary rocks, lastly, the Monactinellids are mostly, if not wholly, represented by the tunnels bored in shells by species of *Cliona*.

Order 4. Tetractinellidæ.—This order comprises marine Sponges in which the skeleton consists of siliceous skeleton-spicules, frequently arranged in bundles in a radiating manner, and held together by spongin. The characteristic skeleton-spicules are tetraxial, the commonest form being that of an elongated rod carrying three shorter summit-rays at the upper end (fig. 49, *d*). In addition to the typical tetraxial spicules there are usually other uniaxial forms, as well as smaller "flesh-spicules," generally of a globate, stellate, or reniform shape.

The Tetractinellid Sponges are largely represented at the present day, the genera *Tethya* and *Geodia* being well-known examples of the group. Owing to the want of a continuous siliceous skeleton, however, the Tetractinellids are not commonly preserved as fossils, and they are usually represented by detached spicules only. The oldest known examples of this order occur in the Carboniferous rocks, which have yielded the remains upon which the genera *Geodites* and *Pachastrella* have been founded. The former of these is supposed to be allied to the recent *Geodia*, and is characterised

by the possession of elongated spicules with bifid or trifid summits, associated with a dermal layer of globate or reniform spicules. The genus *Pachastrella*, again, comprises "massive, nodose, platter-shaped, or irregularly expanded Sponges without a specialised dermal layer" (Hinde). The skeleton is composed of four-rayed spicules, associated with acerate spicules. The oldest species of *Pachastrella* are found in the Carboniferous, but other forms of the genus have been recognised in the Jurassic rocks, the Upper Chalk, and the Eocene Tertiary. In the Upper Chalk occur the remains of various Tetractinellid Sponges, of which the genus *Tethyopsis* is perhaps the most characteristic. In this genus (fig. 53), the skeleton is composed of radiately arranged trifid spicules, mingled with acerates, while the surface is covered with a layer of minute trifid anchorate spicules (Zittel).



Fig. 53.—Part of the skeleton of *Tethyopsis Steinmanni*, from the Upper Chalk. Enlarged 14 times. (After Zittel.)

Order 5. Lithistidæ. — The Sponges included in this order are massive, stony, and thick-walled, with a very variable external figure. The skeleton is composed principally of four-rayed or irregular spicules (fig. 54), which usually branch at their extremities, their ends being blunt, or being furnished with minute articular surfaces. The skeletal spicules are not fused together, but are so interlocked "by the intertwining of their branches or by the close apposition of their expanded extremities" (Hinde) as to give rise to a practically continuous framework (fig. 54, B). There are generally small monaxial "flesh-spicules," and also a dermal layer of trifid or discoid spicules, in addition to the ordinary skeleton-spicules. There may be a single terminal osculum only, or the Sponge may be provided with numerous scattered oscula; while the canal-system exhibits numerous modifications in different groups of the order, and in some cases is not developed as a special structure.

The order of the Lithistid Sponges has been divided by Zittel into the four following sub-orders :—

1. *Rhizomorina.*—In this group of Lithistids the skeleton-spicules are elongated and irregularly branched (fig. 55, B), the branches terminating in minute articular surfaces which unite adjoining spicules into an irregular and confused network. Typical genera are *Cnemidiastrum*, *Seliscothon* and *Verruculina*.

2. *Megamorina.*—In this group the skeleton-spicules are large and either simple or irregularly branched, the branches terminating in obtuse

ends or expanded articular surfaces. The spicules form an open meshwork by the apposition of their terminal facets. Typical genera are *Doryderma*, *Pachypoterion*, and *Carterella*.

3. *Anomocladina*.—In this group the skeleton-spicules have the form of a central node from which radiate simple or bifurcate arms, which have slightly expanded ends, and are variable in number. The skeleton forms a regular network produced by the union of the expanded ends of the spicular arms with the nodes, or sometimes with the branches of adjoining spicules (fig. 55, A). Typical genera are *Vetulina*, *Hindia*, and *Astylospongia*.

4. *Tetracladina*.—In this group, the spicules (fig. 54) consist of four rays which meet in a non-inflated centre in such a way that one ray



Fig. 54.—A, A single skeleton-spicule of the living Lithistid *Discodermia polydiscus*, magnified 60 diameters; B, Small portion of the skeleton of *Siphonia pyriformis*, similarly enlarged. (After Sollas.)

forms a shaft from which the other three rays spring, approximately meeting at angles of 120°. The ends of the rays are branched, and interlock with the ends of adjoining spicules to form a continuous meshwork. Typical examples are the genera *Jerea* (fig. 49, *e*), *Aulocopium*, and *Siphonia* (fig. 58).

The Lithistid Sponges are all inhabitants of the sea, and the existing genera (*Discodermia*, *Corallistes*, *Vetulina*, &c.) are mostly

found in water of moderate depth. As regards the distribution of the order in time, one of the most ancient representatives of the group would appear, from the researches of Dr Hinde, to be the genus *Archæoscyphia* (based upon the *Archæocyathus Minganensis* of Billings), which occurs in the Upper Cambrian rocks (Calciferous series) of Canada, along with allied types such as *Calathium*. Closely related forms are found at a corresponding geological horizon (the Durness Limestone) in Britain. The skeleton in *Archæoscyphia Minganensis* (fig. 56) has the form of a curved funnel attached by its pointed base, and with a deep central cavity or "cloaca" apparently without an internal wall. The constituents of the skeleton have a radial disposition, and distinct spicules, usually four-armed, and inter-



Fig. 55.—A, Part of the spicular network of *Astylospongia*, from the Silurian of Gotland, enlarged 60 times; B, Rhizomorine spicule of *Seliscothon Mantelli*, from the Cretaceous rocks, enlarged 60 times. (After Hinde.)

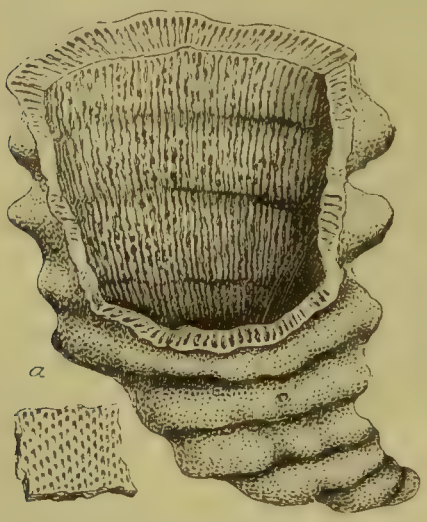


Fig. 56.—Restoration of the lower part of *Archæoscyphia Minganensis*. *a*, The pores of the inner wall of the cup. Ordovician. (After Billings.)



Fig. 57.—Section of *Astylospongia præmorsa*, Silurian, Tennessee. (After Roemer.)

linked by their subdivided ends, are present. The siliceous nature and spicular structure of the skeleton in *Archæoscyphia Minganensis* render it clear that we have to deal here with a genuine Sponge.

In the Ordovician rocks we meet with species of the genera *Hindia* and *Astylospongia*, both of which are represented, still more abundantly in Silurian strata. The genus *Astylospongia* (fig. 57) comprises globular or ovate, unattached sponges, furnished with a cup-shaped or funnel-shaped depression at the summit. There are two principal sets of aquiferous canals, those of the one series being radial and directed from the surface towards the centre, while those of the other series are radial, but are vertically disposed in a direction parallel to the surface, so as ultimately to open into the summit-cup. *Astylospongia* was formerly referred to the Hexactinellids, but recent researches have shown that it is truly referable to the Anomocladine group of the Lithistids. The skeleton consists of siliceous spicules (fig. 55, A) with solid nodes, from which radiate from six to nine straight rays, the ends of which are branched and are furnished with slightly expanded articular processes. The rigid skeletal network is formed by the apposition of the branched ends of the spicules to the nodes of adjoining spicules, or, sometimes, to the ends of their immediate neighbours. More or less closely allied to *Astylospongia* are the Silurian genera *Palæomanon* and *Protachilleum*, and probably the Ordovician genus *Eospongia;* while the Jurassic genera *Melonella* and *Cylindrophyma*, the Cretaceous *Mastosia*, and the recent *Vetulina* are regarded by Zittel as belonging to the same family.

The genus *Hindia* comprises free, spherical or subspherical sponges, in which the body is traversed by numerous canals which radiate from a central space and open on the surface. The skeleton consists of four-rayed spicules, the digitated ends of which embrace the nodes or rays of adjoining spicules in such a way as to form a regular meshwork. The species of the genus are chiefly found in the Ordovician and Silurian rocks, but spicules have been recognised by Hinde in strata of Carboniferous age.

No Devonian Lithistids are at present known, but a few forms of this group (*Cnemidiastrum* and *Doryderma*) have been recognised in the Carboniferous deposits. No forms of the *Lithistidæ* are known in the Permian or Triassic rocks, but very numerous types of this order of sponges have been recognised as occurring in the Jurassic deposits. In the Upper Jurassic rocks of Germany, in particular, are numerous Lithistids, belonging to such genera as *Cnemidiastrum*, *Hyalotragos*, *Platychonia*, *Placonella*, &c. It is, however, in the upper portion of the Cretaceous system that the Lithistid Sponges attain their maximum development, the genera *Chenendopora*, *Siphonia*, *Verruculina*, *Chonella*, *Jerea*, *Jereica*, *Bolidium*, *Turonia*, *Plinthosella*, &c., being characteristic and widely distributed types. Of all the Cretaceous Lithistids none is more generally familiar than the genus *Siphonia* (fig. 58), in which the sponge consists of a pyriform or subspherical body, supported

usually on a longer or shorter stem, and attached thereby to some foreign body. In some cases, however, the stem is wanting, and the sponge is attached simply by diverging root-fibres. The exhalant water-canals open at the summit of the sponge by oscula situated within an apical cavity or cloaca, while the inhalant canals open by pores on the lateral surfaces. The skeleton-spicules (fig. 54, B) are four-armed, the ends of the rays being expanded and furnished with tubercles and intervening depressions, by means of which they are interlocked with the rays of adjoining spicules so as to produce a rigid framework. As pointed out by Sollas, there is a close agreement in form between the spicules of *Siphonia* and those of the recent genus *Discodermia*. The genus *Jerea* is very closely allied to *Siphonia*, but there is no general cloacal chamber; while in the related genus *Hallirhoa* the body of the sponge is lobed.



Fig. 58.—*Siphonia ficus*, a Cretaceous Lithistid Sponge.

In the Tertiary period, lastly, the remains of Lithistids are for the most part of infrequent occurrence, though numerous sponges belonging to this order have been detected in Miocene strata in Algeria.

Order 6. Hexactinellidæ.—In this group of the siliceous Sponges, the skeleton is composed of six-armed flinty spicules, the rays of which are at right angles to each other (fig. 59, B). In the centre of each spicule are three canals cutting each other at right angles, and forming an axial six-rayed tube. In some Hexactinellid Sponges, the spicules are simply united by the soft tissues. More commonly, the spicules are fused with one another by the ends of corresponding rays, or are united by means of amorphous silica, so as to form a trellis-work of rectangular or polyhedral meshes, the individual spicules of which may be only recognisable by the persistence of their axial canals (fig. 63). The "flesh-spicules" are fundamentally six-armed, but may give off secondary branches so as to form a rosette.

The Hexactinellid Sponges may be divided into two groups according as the skeletal spicules are fused with one another or are free. In the group of the *Dictyonina*, comprising such genera as *Euplectella*, *Ventriculites*, *Tremadictyon*, *Cœloptychium* (fig. 59), and many others, the skeleton is composed of six-armed spicules which became fused with one another by a secondary deposit of silica, so as to form a latticed trellis-work. On the other hand, in the group of the *Lyssakina*, comprising such genera as *Stauractinella* and *Hyalostelia*, the skeletal spicules are interlaced, and are usually

simply held in position by the soft parts of the sponge, no fusion taking place between them.

The recent Hexactinellids are all inhabitants of the sea, and are mostly found in deep water, and palæontologists are now acquainted with a very extensive series of fossil forms, dating from the Cam-

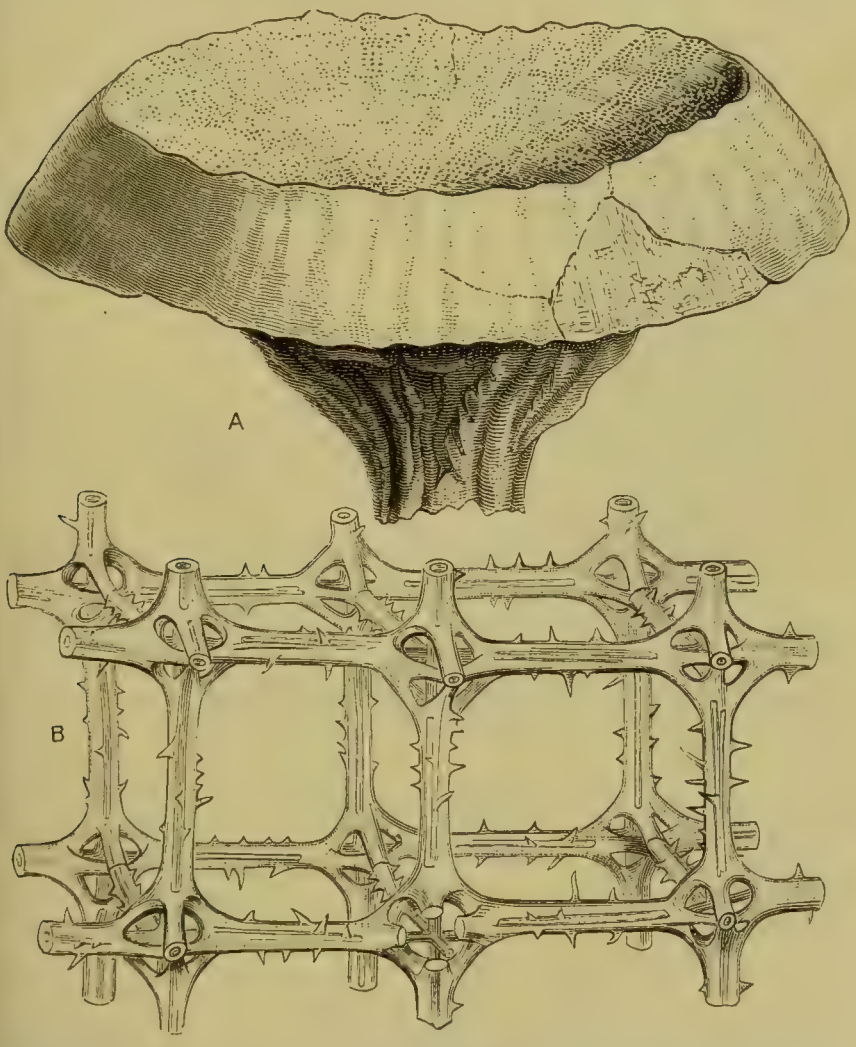


Fig. 59.—A, Side-view of a specimen of *Cœloptychium Seebachi*, of the natural size, from the Cretaceous formation; B, Portion of the hexradiate skeleton of the same, enlarged 65 times. (After Zittel.)

brian period. The oldest known type of the *Hexactinellidæ* is the genus *Protospongia*, species of which occur in deposits of Cambrian age. In this genus, the sponge is cup-shaped, with a thin wall, composed of large cruciform spicules arranged so as to form a quadrate network, the interspaces of which are filled up by similarly dis-

posed cross-shaped spicules of smaller size (fig. 50). Owing to the condition of preservation of the sponge, it is still not absolutely certain whether the spicules were fused with one another or free, but it would seem probable that the former was the case, and that the genus belongs therefore to the Dictyonine section of the Hexactinellids.

Another very ancient genus of this order is *Hyalostelia*, one of the Lyssakine section of the Hexactinellids, which is first known in the Cambrian deposits, is found in Ordovician and Silurian strata, and is abundantly represented in the Carboniferous rocks. Detached spicules from the Chalk have also been referred here. The genus *Hyalostelia* is related to the recent genus *Hyalonema*, comprising the so-called "Glass-rope Sponges." The body of the Sponge in *Hyalostelia* is imperfectly known, but is composed of siliceous spicules some of which are of the hexactinellid type, with one ray much elongated, while others are variously modified. The sponge was attached to the sea-bottom by a long "rope" of cylindrical or rod-like, siliceous "anchoring spicules," which often terminate at their distal ends in four recurved rays (fig. 60). The "rope" is the part usually found in the fossil condition, and in the case of the *Hyalostelia parallela* of the Carboniferous rocks it was originally described as a tubicolar Annelide, under the name of *Serpula parallela*.



A B

Fig. 60.—A, Part of the anchoring-rope of *Hyalostelia Smithii*, from the Carboniferous Limestone, of the natural size; B, Fragment of one of the anchoring spicular rods of the same species, showing four recurved rays at the distal end, enlarged ten diameters. (After Hinde.)

In strata of Ordovician age, the Hexactinellid Sponges are represented not only by the genus *Hyalostelia*, but also by the singular group of the *Receptaculitidæ*, the true relations of which have been recently determined by Dr George J. Hinde. The two principal genera of this family—viz., *Receptaculites* and *Ischadites*—have long been known to palæontologists, but the investigation of their structure has proved to be attended with great difficulties, and various opinions have been held as to their relations and systematic position. In *Receptaculites* (fig. 61) the organism is a cup-shaped or platter-shaped body which grows from a small inversely conical

nucleus, and may reach a foot or more in diameter, but is not attached by a stem to the sea-bottom. In the nearly allied *Ischadites*, the organism is conical, ovate, or pyriform in shape, with a summit-aperture leading into a central cavity. In *Receptaculites*, on the other hand, there is no distinct evidence that the cup-shaped cavity was ever roofed over as it is in *Ischadites*. The internal

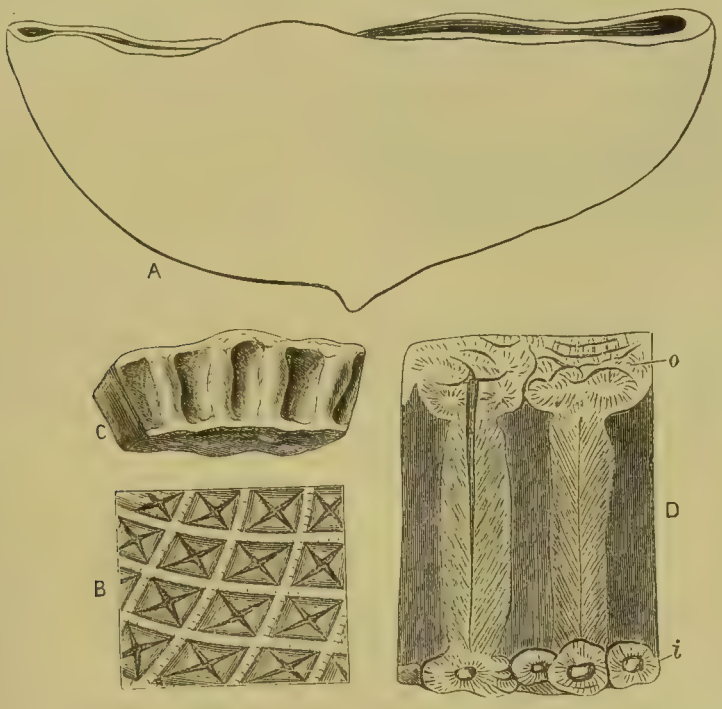


Fig. 61.—Morphology of *Receptaculites*. A, Outline of a perfect, basin-shaped specimen of *Receptaculites Neptuni*, viewed in profile, of the natural size; B, Part of the outer integument of the same, enlarged two diameters, and so far weathered as to show the four transverse or horizontal rays which underlie the summit-plates of the skeleton-spicules; C, Side-view of a fragment of the same, showing the skeletal spicules; D, Vertical section of the same, magnified, showing the skeletal spicules with their axial canals and expanded extremities. From the Devonian of Germany. (After Gümbel.)

structure of these singular organisms will be best understood by reference to fig. 62, which is an ideal figure constructed by Mr Billings to show the morphological characters of *Receptaculites*. It should be noted, however, that this figure, though well representing the *structure* of *Receptaculites*, gives an incorrect idea of the *form* of the organism; since the known species of this genus are cup-shaped and open superiorly, as shown in fig. 60, A. The cup-shaped body of *Receptaculites* is furnished with a thick wall composed of pillar-like spicules arranged at right angles to the surface. These spicules are shown in thin sections (fig. 61, D) to be furnished in their interior with an axial canal, and they are expanded at their outer ends

into rhomboidal "summit plates" (fig. 61, B), which fit into one another so as to form a mosaic-like outer layer or membrane, the plates being disposed in decussating lines. Immediately below, or internal to, the summit-plates, the vertical spicules give off four transverse or horizontal rays, which only become visible externally when the surface-plates are worn away or are viewed from the inside (fig. 61, B). At their inner ends, where they abut upon the central cavity of the organism, the vertical spicules expand so as to form small horizontal plates (fig. 62, *b*), which are traversed by horizontal canals, and are so apposed to each other as to give rise to an inner calcareous membrane. In one species of the genus, if not in all, the plates of this inner membrane are so disposed as to leave cylindrical canals at their angles of junction, through which the water which has filtered between the summit-plates of the outer layer of plates is admitted to the internal cavity of the organism. In most specimens of *Receptaculites* the skeleton-spicules are now composed of calcite or peroxide of iron, but Hinde has adduced evidence to show that the spicules were originally siliceous, and that their present condition is the result of replacement. The species of *Receptaculites* are widely distributed in the Ordovician and Silurian deposits, and are also well represented in the Devonian rocks, while a species is recorded as occurring in the strata of Carboniferous age.

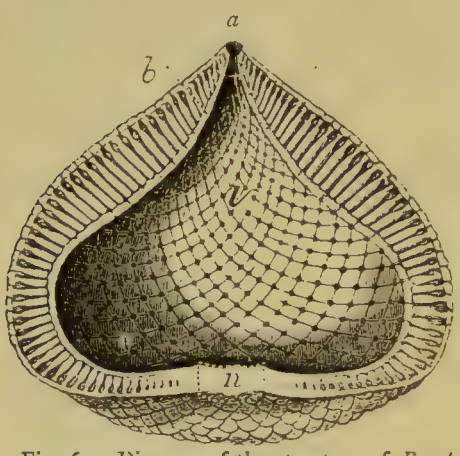


Fig. 62.—Diagram of the structure of *Receptaculites*, as it would be shown by a vertical section of a perfect specimen. *a*, The aperture at the summit; *b*, The inner plates of the spicules; *c*, The summit-plates of the spicules; *n*, The usual position of the nucleus; *v*, The great internal cavity. The unshaded bands running from the outer to the inner integument represent the spicules. (After Billings.) The *form* of this figure agrees with that of *Ischadites*, the body in *Receptaculites* being of the nature of an open cup or bowl.

The genus *Ischadites*[1] comprises fossils which are in many respects closely allied to *Receptaculites*, but in which the central cavity is roofed over superiorly, instead of being widely open as it is in the latter genus. The *form* of the organism is, therefore, that represented in the diagrammatic figure of *Receptaculites* given above (fig. 62), being conical or pyriform, usually with a summit-perforation opening into the central cavity. The wall of the organism is composed of cylindrical, pillar-like spicules, arranged at right angles to the surface, and in most respects similar to the corresponding structures in *Receptaculites*. The outer ends of these hexactinellid spicules are modified to form rhomboidal

[1] The fossils to which the name *Tetragonis* have been given belong in part to *Ischadites*, and are in part referable to the Hexactinellid genus *Dictyophyton*.

"summit-plates," which are nearly in contact, and are arranged in obliquely curved intersecting rows, giving the external surface of the fossil very much the appearance of the engine-turned case of a watch. Internal to the summit-plate, each radial spicule gives off four transverse or horizontal rays, as in the genus *Receptaculites;* but the inner ends of the radial spicules simply terminate in pointed extremities, and there is, therefore, no internal plated membrane such as characterises the latter genus. The species of *Ischadites* are found in the Ordovician rocks, and, more abundantly, in Silurian deposits, but they are not known to have survived into the Devonian period. Nearly allied to *Ischadites* is the genus *Acanthochonia*, which is also of Silurian age. Lastly, the genus *Sphærospongia* includes pyriform or cup-shaped organisms, the outer integument of which consists of regularly arranged hexagonal calcareous plates, which represent the expanded outer ends (or "summit-plates") of a series of Hexactinellid spicules. Immediately below, or internal to, the summit-plate, each spicule gives off four transverse or horizontal rays, but the actual stem of the spicule, or, in other words, its radial ray, is either aborted or is represented only by a short knob-like projection. The species of *Sphærospongia* are confined, so far as known, to the Devonian rocks.

In spite of their abnormal form and structure, as compared with recent types, there seems to be no reason for doubting that Dr Hinde is correct in his view that the genera *Receptaculites*, *Ischadites*, *Acanthochonia*, and *Sphærospongia* constitute a peculiar group of Lyssakine Hexactinellid Sponges, all the members of which are Palæozoic.

In rocks of Silurian age, the Hexactinellid Sponges are represented not only by the Anchoring-Sponges belonging to the genus *Hyalostelia* and by the abnormal genera of the *Receptaculitidæ* just noticed, but also by the curious types known as *Dictyophyton* and *Plectoderma*. The genus *Dictyophyton* comprises cylindrical or cup-shaped sponges, apparently not attached to foreign bodies, in which the wall consists of a connected spicular framework disposed so as to form a series of quadrangular areas. The precise structure of the spicules and their mode of union are points as yet imperfectly known. The species of *Dictyophyton* are not only found in the Silurian rocks, but likewise in Devonian strata, and species occur also in the Carboniferous deposits. The Silurian genus *Plectoderma* is related to *Dictyophyton*, but the spicular network is much less regular.

In the Devonian deposits, the groups of Hexactinellids represented by *Sphærospongia* and *Dictyophyton* still persist, but our knowledge of other types is very imperfect. In the Carboniferous period, again, the Hexactinellids are chiefly represented by the genus *Hyalostelia*, the anchoring fibres of which are not very uncommon in the lower beds of the system; but other genera of the *Lyssakina* (such as *Holasterella*) are likewise represented.

In the Permian and Triassic systems, so far as our certain knowledge goes, Hexactinellid Sponges may be said to be still unknown; though the imperfectly examined *Bothroconis* of King, from the Permian of the North of England, may possibly belong here.

On the other hand, in the Jurassic rocks the Hexactinellid Sponges, though comparatively few in number in the lower division of the system, attain a great development in the upper beds of the system, in certain regions. Of the Jurassic Hexactinellids, *Craticularia*, *Verrucocœlia*, *Tremadictyon* (fig. 63), *Sporadopyle*, and *Sphenaulax* possess a skeleton built upon the same type as the recent *Eurete* and *Farrea*; *Pachyteichisma* and *Trochobolus* are early forms of the great



Fig. 63.—Portion of the skeleton of *Tremadictyon reticulatum*, enlarged 50 diameters, from the Jurassic rocks. (After Zittel.) The original spicules are soldered into a continuous trellis-work by a coating of silica; but their position and hexradiate form is shown by their axial canals. The "crossing-nodes," or points of intersection of the arms of each spicule, are solid.

family of the *Ventriculitidæ*; *Cypellia*, *Stauroderma*, and others represent the extinct family of the *Staurodermidæ*; and *Stauractinella* belongs to the group of Hexactinellids (*Lyssakina*) in which the skeleton-spicules are only united by sarcode, so that they do not form a continuous network.

In the Cretaceous deposits, and especially in the Chalk itself, the Hexactinellids are very largely and abundantly represented. Of the family of the *Euretidæ*, with their regular spicular mesh and simple spicular nodes, we have now few forms (*Craticularia*, *Verrucocœlia*, &c.); but the great family of the *Ventriculitidæ* and the groups allied to this now undergo a marvellous expansion. In the *Ventriculitidæ* proper, the sponge-body is of variable shape, but usually more or less cup-shaped or infundibuliform (figs. 64 and 65), or cylindrical, the wall being often folded. The skeleton-spicules are always united into a continuous lattice-work, and their "crossing-nodes" are not solid. On the other hand, the point of intersection of the arms of each hexradiate spicule forms an open octahedron, in the centre of

which the central canals of the six rays form a delicate axial cross. The boundaries of the central space are formed by twelve oblique uniting beams, the whole forming an elegant octahedron, which is known as the "lantern" (see the same type of spicule in *Cœloptychium*, fig. 59, B). The sponge-body in the *Ventriculitidæ* was attached to the sea-bottom by a root of fasciculate flinty fibres, and a dermal layer in the form of a cribriform siliceous membrane was



Fig. 64.—*Ventriculites sp.* White Chalk, Britain.

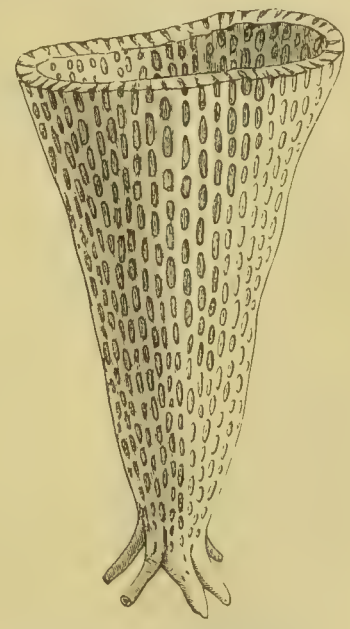


Fig. 65.—*Ventriculites striatus*, from the Cretaceous rocks of Hanover, one-half of the natural size.

present. Typical Cretaceous genera of the *Ventriculitidæ* are *Ventriculites* itself (figs. 64 and 65), of which numerous species are known, *Rhizopoterion* and *Cephalites*.

Closely allied to the preceding is the family of the *Cœloptychidæ*, comprising the beautiful Chalk Sponges which constitute the genus *Cœloptychium* (fig. 59). These are in most respects very similar to *Ventriculites*, but have a flattened or discoid body supported on a short stem, the skeleton being folded into laminated walls which divide the central cavity into radial chambers.

The group of the *Mæandrospongidæ* is also closely related to that of the *Ventriculitidæ*, and comprises variably shaped sponges with folded walls, the folds often anastomosing so as to give rise to open tubes. The genera of this family—such as *Plocoscyphia*, *Tremabolites*, *Etheridgia*, *Toulminia*, and *Camerospongia* (fig. 66)—are mostly Cretaceous, though a few types occur in the Jurassic deposits.

As regards the remaining groups of the Cretaceous Hexactinellids, the body-wall in the family *Callodictyonidæ* is composed of hexactinellid spicules the nodes of which are octahedral, and which give rise by their union to an exceedingly regular open meshwork, while the canal-system is wanting or rudimentary. The Cretaceous genera

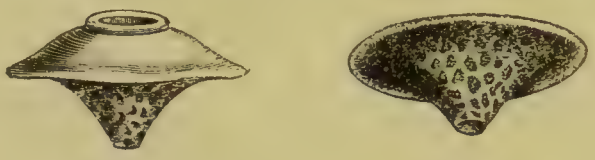


Fig. 66.—*Camerospongia fungiformis.* Cretaceous.

Callodictyon and *Pleurope* are good representatives of this family. In the *Mellitionidæ*, are included Sponges in which the walls are closely perforated by tubular canals like the cells of honeycomb, and the spicules have simple nodes. This family includes the Cretaceous genus *Stauronema* and the genus *Aphrocallistes*, which ranges from the Chalk to the present day. The family of the *Coscinoporidæ* comprises variously shaped Sponges, with a close and irregular skeletal network, and having numerous straight, blind, radiate canals which open alternately on both sides of the sponge-wall. In *Coscinopora* itself (fig. 67), the cup-shaped sponge-body is affixed to some foreign object by ramified roots. The lattice-work of the skeleton is irregular, and the crossing-nodes of the spicules are partly solid and partly furnished with a "lantern." In the nearly allied *Guettardia*, which is also Cretaceous in its range, the wall is deeply folded in a stellate manner, and the crossing-nodes of the spicules are solid. Nearly related to the preceding is the family of the *Staurodermidæ*, which, though principally Jurassic in its range, is not without Cretaceous representatives (such as *Eubrochus*).

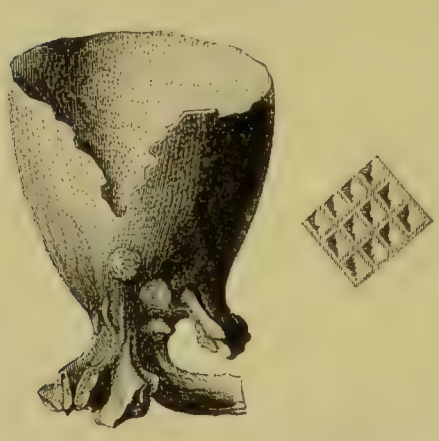


Fig. 67.—*Coscinopora cupuliformis*, and a portion of its surface enlarged. Cretaceous.

The Tertiary Hexactinellids, finally, are comparatively few in number and are imperfectly known, but the order is represented at the present day by such genera as *Euplectella*, *Hyalonema*, *Aphrocallistes*, *Holtenia*, *Eurete*, *Farrea*, and many others.

Before leaving the Hexactinellid Sponges, a few words may be added with regard to the Silurian genus *Amphispongia*, the char-

acters of which are in some respects anomalous. In this curious genus (fig. 68, *c* and *d*) the sponge-body is elliptical, greatly compressed, and free, without any traces of a canal-system. The basal

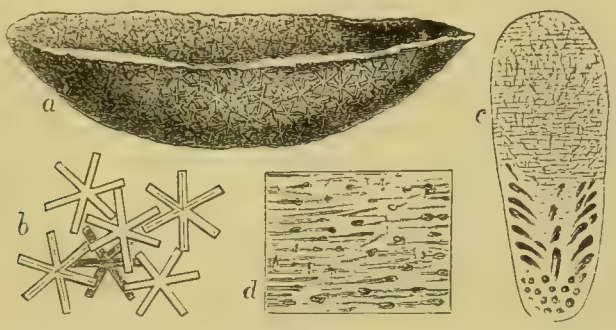


Fig. 68.—*a*, Side-view of a specimen of *Astræospongia meniscus*, of the natural size, Silurian; *b*, Spicules of the same, enlarged (after Roemer); *c*, A split specimen of *Amphispongia oblonga*, of the natural size, Silurian; *d*, Part of the upper portion of the same, enlarged. (Original.)

portion of the sponge consists of large conical spicules, arranged with their pointed lower ends converging towards the middle line; while the upper portion consists of "slender four- and five-rayed spicules with the rays at right angles to each other" (Hinde). The spicules are not fused with one another, and their arrangement is peculiar. In spite of its aberrant character, however, it would seem that *Amphispongia* should be regarded as belonging to the *Hexactinellidæ*.

ORDER 7. OCTACTINELLIDÆ.—This order is represented only by the single genus *Astræospongia*, and is characterised by the presence of skeleton-spicules which are normally eight-rayed, six of the rays radiating at equal angles from a central point (fig. 68, *b*), while the other two rays form a vertical axis. The spicules are not fused with one another, and the vertical rays are often obsolete or wholly wanting. The sponges which constitute the genus *Astræospongia* (fig. 68, *a*) are discoid or basin-shaped in form, without any stem of attachment, and without any definite canal-system. The spicules have the form above described, and are now usually found in the condition of calcite. According to the views of Dr Hinde, however, the present calcareous condition of the spicules is the result of secondary changes or replacement, and the skeleton was originally

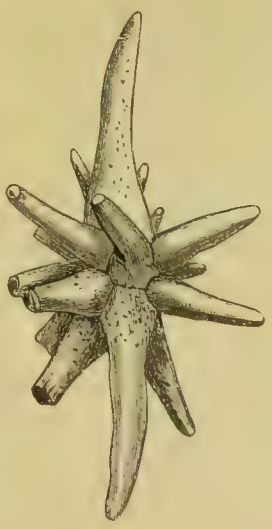


Fig. 69.—Skeleton-spicule of *Asteractinella expansa*, one of the Heteractinellid Sponges, from the Carboniferous rocks, enlarged ten diameters. (After Hinde.)

siliceous. The oldest known species of *Astræospongia* appear in the Silurian, but the genus is principally characteristic of the Devonian system.

Order 8. Heteractinellidæ.—This group has been founded by Hinde to include certain Palæozoic siliceous Sponges in which the skeleton-spicules consist of "an indefinite number of rays, varying from six to thirty, radiating from a common centre" (fig. 69). The body-spicules are irregularly disposed and are not fused with one another; but the dermal spicules are interwoven together, and their rays are partially or completely fused with one another. The genera *Tholiasterella* and *Asteractinella* (fig. 69), included by Hinde in this group, are confined to strata of Carboniferous age, and are only known by detached spicules or imperfect fragments.

Class II. Calcispongiæ.

The class of the Calcareous Sponges comprises, as the name implies, all those sponges in which the skeleton is composed of spicules of carbonate of lime. The spicules vary considerably in form, and different forms are often associated in the same sponge. In living Calcisponges the spicules are never fused with one another, nor united by horny fibre, but in the group of fossil Calcisponges described by Zittel under the name of *Pharetrones*, the skeleton is formed by a reticulated calcareous fibre which is "wholly composed of spicules in close approximation to each other, and as closely interwoven together as the strands of a rope" (Hinde). The following are the principal types of spicules found in the calcareous Sponges. (*a*) Simple uniaxial spicules, which may be associated with the other forms of spicules, or, as in *Pharetrospongia*, may be the only forms present. (*b*) Three-rayed spicules, in which all the rays are in one plane and the rays and angles are equal (figs. 70 and 71, B). In some cases the spicules are triradiate, but two of the three rays are paired and equal, and the third ray is longer or shorter than the other two. (*c*) Four-rayed spicules, with three rays equal and in one plane, but with a fourth ray directed at right angles or obliquely to the others.

The recent Calcisponges are all of small size and are inhabitants of comparatively shallow water, all being marine. By Vosmaer the *Calcispongiæ* are divided into the following two orders:—

Order 1. Homocœla.—In this order there are no special "flagellated chambers," and the canal-system can hardly be said to exist in a definite form; but the thin walls of the sponge (fig. 70) are perforated by numerous pores opening directly into a general cavity, which is lined by ciliated epithelium and terminates on the surface by a single osculum. The order corresponds with the

Ascones of Haeckel, and includes the recent genus *Leucosolenia* (=*Ascetta*). No fossil forms belonging to this order are known to occur.

Order 2. Heterocœla.—In this order "flagellated chambers" are present, and there is a canal-system of different form in the different families of the order. In the family of the *Syconidæ* (=the *Sycones* of Haeckel) the flagellated chambers are elongated, and constitute a series of radial tubes which open directly into a central cloacal chamber. This family includes such recent genera as *Grantia* and *Sycon*, together with the Jurassic genus *Protosycon*. This latter is the earliest representative of the modern Calcisponges, and possesses a cylindrical or clavate body, with a long tubular cloaca, and having the three-rayed or four-rayed spicules so disposed as to form a series of radial canals.

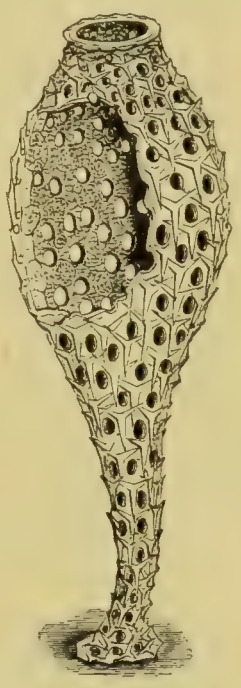


Fig. 70.—*Ascetta primordialis*, a simple Calcareous Sponge, enlarged fifty times. (After Haeckel.)

In the family of the *Leuconidæ* (=the *Leucones* of Haeckel) the flagellated chambers are mostly rounded, and are placed in communication with the cloacal chamber by exhalant canals; while the skeletal spicules are arranged in no definite order. This family includes such recent genera as *Leuconia* and *Leucandra*, detached spicules of both of which have been recognised in the Pliocene beds of St Erth, Cornwall. Very closely allied to this family is the group of the *Teichonidæ*, of which no fossil forms are known.

Lastly, we have the large and important group of the *Pharetronidæ* (the *Pharetrones* of Zittel), all the members of which are extinct. This group includes the largest and most massive of all the Calcisponges, and its characters depart in many important respects from those of all recent forms. The Sponges included by Zittel under the name of *Pharetrones* are variably shaped, simple or branched sponges, with thick walls, and attached by their bases to foreign bodies. In some forms (*e.g.*, in *Peronella*) the canal-system is not distinctly developed, but there is usually a special system of irregular, branched water-canals. The skeleton consists of calcareous spicules disposed to form a network of solid anastomosing fibres (fig. 71, D), and there is a well-developed smooth or wrinkled dermal membrane.

The earliest known types of the *Pharetrones* appear in the Devonian rocks, and belong to the genus *Peronella*, which in later

deposits is represented by very numerous forms. In this genus, the sponge is simple or branched, there is no definite canal-system, and the skeleton consists (where its structure can be determined at all) of anastomosing calcareous fibres composed of comparatively large three-rayed and four-rayed spicules surrounded by similar spicules of small size. Little is known of the *Pharetrones* of the Carboniferous and Permian deposits; but the Upper Triassic beds have yielded numerous forms belonging to such genera as *Eudea*, *Verticillites*, *Peronella*, *Corynella*, and *Stellispongia*. In the Jurassic and Cretaceous rocks the remains of *Pharetrones* are often very abundant, and belong to very numerous genera. Of the many

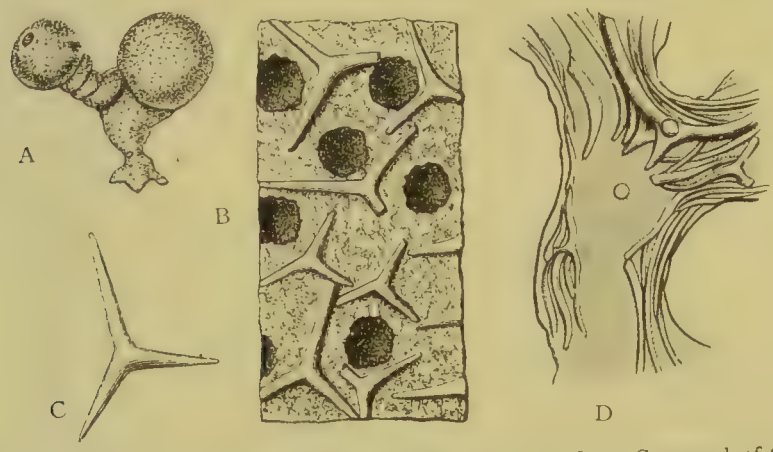


Fig. 71.—*Pharetrones*. A, *Tremacystia D'Orbignyi*, from the Upper Greensand, of the natural size; B, Portion of the outer surface of the same, showing the pores and the spicules of the dermal layer, enlarged thirty times; C, Detached three-rayed spicule, belonging to the dermal layer, enlarged seventy-two times; D, Fragment of the skeleton-fibre of *Elasmostoma scitulum*, showing large three-rayed and four-rayed spicules with small filiform spicules, from the Upper Chalk, enlarged fifty times. (After Hinde.)

Jurassic genera, *Corynella* is perhaps the most important. In this genus we have sponges allied to *Peronella*, but usually possessing a distinct canal-system, and having the reticulated skeleton-fibre composed of "minute, filiform, three-rayed spicules disposed generally parallel with each other in the direction of the fibre" (Hinde). Other largely represented Jurassic genera are *Stellispongia*, *Sestrostomella*, and *Lymnorea*. Of the Cretaceous *Pharetrones*, the genera *Peronella* and *Corynella* still hold a predominant place, but many other types are present, such as *Oculospongia*, *Tremacystia*, *Elasmostoma*, and *Pharetrospongia*. In the genus *Tremacystia* (fig. 71, A) the sponge-body is formed of connected hollow segments, with a common axial tube, and the wall is formed by a single layer of reticulated calcareous fibres penetrated by numerous minute canals. The dermal layer (fig. 71, B and C) is formed of relatively large three-rayed and four-rayed spicules; while the skeleton-fibres are

composed of minute filiform triradiate spicules. In *Elasmostoma* (fig. 71, D) the fibres of the skeleton are composed of large three-rayed and four-rayed spicules, arranged in the centre of the fibre and surrounded by smaller sinuous spicules. Lastly, in the genus *Pharetrospongia*, regarded by Professor Sollas as a Halichondroid Sponge, the skeleton-fibre is composed of minute, straight or slightly curved, uniaxial spicules, arranged parallel with one another in the direction of the fibre.

The latest known representatives of the *Pharetrones* occur in the Maestricht Chalk, but no examples of this group of sponges have been as yet detected in any strata of Tertiary age, nor are any recent forms recognised which could be referred to this remarkable division of Calcisponges.

LITERATURE.

1. "Porifera." Bronn's 'Klassen und Ordnungen des Thier-Reichs,' vol. ii. (New Ed.), 1882-87. G. Vosmaer.
2. "Die Kalk-Schwämme." Haeckel. 1872.
3. "Handbuch der Palæontologie," vol. i., part 2, 1879. Zittel.
4. "Studien über fossile Spongien." 'Abhandl. d. k. bayer. Akad. der Wiss.' 1877 and 1878. Zittel. (The three important memoirs published by Zittel under the above title are translated into English by Mr W. S. Dallas in the "Annals and Magazine of Natural History," for 1877, 1878, and 1879).
5. "Beiträge zur Systematik der fossilen Spongien." 'Neues Jahrbuch für Mineralogie,' &c., 1877, 1878, 1879. Zittel.
6. "Ueber Cœloptychium. Ein Beitrag zur Kenntniss der Organisation fossilen Spongien." 'Abhandl. der k. bayer. Akad. der Wiss.' Bd. xii. 1876. Zittel.
7. "Ueber Astylospongidæ und Anomocladina." 'Neues Jahrb. für Mineralogie,' &c., 1884. Zittel.
8. "Die Spongitarien des Nord-deutschen Kreide-gebirges." 'Palæontographica,' 1864. F. A. Roemer.
9. "Paléontologie de la Province d'Oran." 5th Fasc. "Spongiaires," 1872. Pomel.
10. "Lethæa Palæozoica." Ferdinand Roemer. 1880.
11. "Ventriculitidæ of the Chalk." 'Annals Nat. Hist.,' 1847-48. Toulmin Smith.
12. "Beiträge zur Kenntniss der Organisation und systematischen Stellung von Receptaculites." C. W. Gümbel. 'Abhandl. der k. bayer. Akad. der Wiss.' Bd. xii. 1876.
13. "Catalogue of the Fossil Sponges in the British Museum." 1883. Hinde.
14. "A Monograph of the British Fossil Sponges." Palæontographical Society, 1887-88. Hinde.
15. "On the Structure and Affinities of the Family Receptaculitidæ." 'Quart. Journ. Geol. Soc.' Vol. xl. 1884. Hinde.
16. "On Beds of Sponge-remains in the Lower and Upper Greensands of the South of England." 'Phil. Trans.,' 1885. Hinde.
17. "Notes on Fossil Calcispongiæ." 'Ann. & Mag. Nat. Hist.,' 1882. Hinde.

18. "Structure and Affinities of the Genus Siphonia." 'Quart. Journ. Geol. Soc.' Vol. xxxiii. 1877. Sollas.
19. "On Pharetrospongia Strahani." 'Quart. Journ. Geol. Soc.' Vol. xxxiii. 1877. Sollas.
20. "On the Structure and Affinities of the Genus Protospongia." 'Quart. Journ. Geol. Soc.' Vol. xxxvi. 1880. Sollas.
21. "On the Flint Nodules of the Trimmingham Chalk." 'Ann. and Mag. Nat. Hist.,' 1880. Sollas.
22. "On Fossil Sponge-Spicules from the Carboniferous Strata of Ben Bulben." 'Ann. & Mag. Nat. Hist.,' 1880. Carter.
23. "Further Observations on the So-called 'Farringdon Sponges.'" 'Ann. & Mag. Nat. Hist.,' 1883. Carter.
24. "Die Pharetronen aus dem Cenoman von Essen, und die systematische Stellung der Pharetronen." 'Palæontographica.' Bd. 29, 1883. Dunikowski.
25. "Beiträge zur Kenntniss der Spongien der böhmischen Kreide-formation." 'Abhandl. der k. böhm. Gesell. der Wiss.' 1883-85. Pocta.
26. "Descriptions of Fossil Reticulate Sponges, constituting the Family Dictyospongidæ." 'Thirty-fifth Ann. Rep. on the State Cabinet. 1884. Hall.
27. "Remarks on Dictyophyton." 'Bulletin of the Amer. Mus. Nat. Hist.,' 1881. Whitfield.

CHAPTER XII.

FOSSILS OF DOUBTFUL AFFINITIES.

I. Archæocyathinæ.

The lowest Cambrian strata ("*Olenellus* Beds") of North America, Spain, and Sardinia have yielded the remains of a number of remarkable organisms, which may be collectively spoken of as the *Archæocyathinæ*, but which cannot at present be definitely referred to their place in the zoological series. The three genera which may be regarded as typical of this group of organisms are *Archæocyathus*, *Ethmophyllum*, and *Spirocyathus*, and the characters of these may be briefly treated of here.

There is some difficulty in determining for which of the species described by Mr Billings under the name of *Archæocyathus* this generic title should be retained. If, however, we follow Hinde, and accept *Archæocyathus profundus*, Bill., as the type of the genus, we have to deal with elongated, turbinate, more or less curved fossils, sometimes more than a foot in length, with a diameter of from two to four inches, having a general resemblance to such Rugose Corals as the simple species of *Cyathophyllum*. The conical skeleton is hollow, with a deep, cup-shaped internal cavity, the surface of which shows radiating ridges, and is bounded by a thin inner wall (fig. 72, A). Both the inner and outer walls are perforated by pores, and the space between the two is traversed by numerous vertical septa, which are in turn connected by delicate dissepiments, giving the general structure a vesicular character (fig. 72, B). *Archæocyathus profundus* seems to have been undoubtedly calcareous in its original constitution, and there is no evidence that its skeleton was at any time composed of spicules. The original specimens were obtained in the Cambrian strata of the Straits of Belle Isle, Labrador.

The genus *Ethmophyllum*, as based upon the fossils described by Mr Meek from the Cambrian strata of Nevada under the name of *E.*

Whitneyi, comprises organisms with a general resemblance to *Archæocyathus*. The skeleton in this genus is also superficially very similar to a simple Rugose Coral, being cup-shaped, turbinate, or cylindrical, and either straight or curved (fig. 72 *bis*, A), the external surface being sometimes concentrically annulated or vertically ribbed. There is a deep internal cup (fig. 72 *bis*), the lining of which is perforated by numerous round or oval pores, similar perforations, arranged in vertical and horizontal rows, existing in the outer wall as well. The space between the inner and outer membranes is subdivided by a number (from six to over one hundred) of vertical radiating partitions (fig. 72, B), which have a general resemblance to the "septa" of the Madreporarian Corals. These radiating septa are usually perforated by rounded apertures, which place contiguous interseptal chambers in communication; and they are commonly connected together by irregular transverse plates, resembling the "dissepiments" of many corals. The whole structure of the skeleton is thus more or less porous, and a characteristic feature of the genus is the presence of oblique funnel-shaped canals leading into the internal cup. As in the preceding genus, the skeleton is now calcareous, and microscopic sections show nothing which would prove that its constitution was at any time essentially different, or that definite spicules existed. By Mr Walcott, the fossil described by Mr Billings under the name of *Archæocyathus Minganensis* has been referred to the genus *Ethmophyllum;* but, as previously pointed out, the researches of Dr Hinde have shown that this form was originally siliceous, with a spicular skeleton, and that it is truly referable to the Lithistid Sponges.

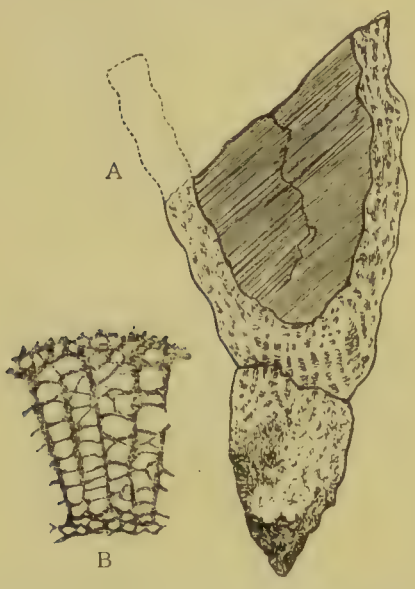


Fig. 72.—A, Longitudinal section of a small specimen of *Archæocyathus profundus*, Bill., slightly reduced in size, showing the reticulated structure of the skeleton and the deep cup at the summit; B, Part of a transverse section of the same, enlarged, showing that the reticulated skeleton has a distinct radial structure, the septa being connected by dissepiments. Cambrian, Labrador. (After Walcott.)

On the other hand, the fossils described by Billings from the Cambrian rocks of Canada under the name of *Archæocyathus atlanticus* would seem to differ considerably in structure from *Archæocyathus* proper (as based upon *A. profundus*, Bill.); and they have recently been referred by Hinde to a new genus under the name of *Spirocyathus* (apparently related to the *Protopharetra* of Bornemann).

The skeleton in *Spirocyathus atlanticus* is conical in form, with a general resemblance to a simple coral, its interior being occupied by a longitudinal tubular cavity (fig. 72 *bis*, C and D). The space between the inner and outer walls is occupied by reticulated calcareous tissue, in which a radial structure is hardly recognisable, while distinct vertical "septa" do not appear to be present. The spaces or irregular canals formed by this calcareous reticulation open on both the outer and inner surfaces of the skeleton by rounded or oval pores. In this case, also, the skeleton seems to have been originally calcareous, and there is no evidence of any spicular structure. *Spirocyathus atlanticus* occurs in the Cambrian rocks of Canada and the United States, and apparently allied types have been discovered by Bornemann in strata of the same age in Sardinia, and have been described by him under the name of *Protopharetra*.

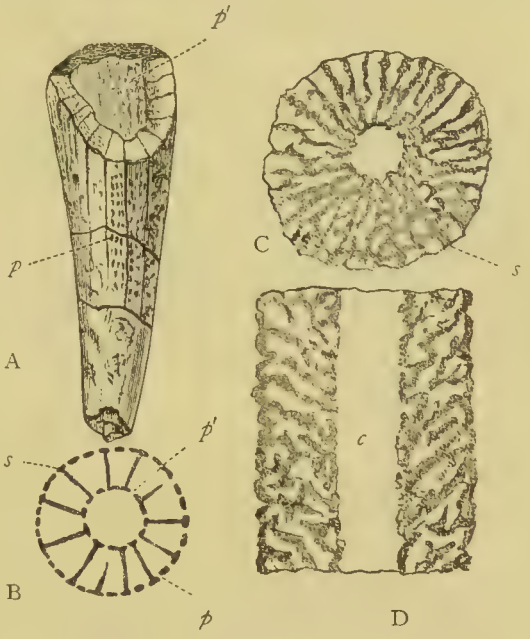


Fig. 72 *bis*.—A, A specimen of *Ethmophyllum Rensselæricum*, Ford, of the natural size; B, Transverse section of the same, showing the outer and inner walls and the radiating septa (*s*); C and D, Transverse and longitudinal sections of *Spirocyathus atlanticus*, Bill. sp. *p*, Pores in the outer wall; *p'*, Pores in the inner wall; *c* The internal cup or chamber. From the Cambrian rocks of North America. (After Walcott.)

The *Archæocyathinæ* are among the most ancient of all known fossils, and are therefore of peculiar zoological interest. It is not, however, possible at present to come to any absolutely certain conclusion as to their systematic position. As their skeleton seems to have been undoubtedly originally calcareous, and as there is no certain evidence (now that the form described by Billings as *Archæocyathus Minganensis* is known to be a Sponge) that their structure was spicular, it would not be possible to refer the group to the *Porifera*. On the other hand, as pointed out by Hinde, the *Archæocyathinæ* show certain unquestionable points of relationship to the Madreporarian Corals. This is particularly seen in the reticulated structure and usually more or less radiate arrangement of the skeletal framework, the skeleton being in many respects comparable with that of such a Perforate Coral as *Calostylis*. At the

same time, the skeleton departs widely in certain of its features (such as the presence of a distinct perforated internal wall) from the Madreporarian type. Upon the whole, therefore, in the present state of our knowledge, it seems best to regard the *Archæocyathinæ* as a group of uncertain affinities, probably more closely allied to the *Madreporaria* than to any other division of the animal kingdom.

II. Pasceolus, Cyclocrinus, and Nidulites.

We may briefly consider here a series of fossils the true affinities of which are at present absolutely uncertain, and which have no particular claim to be taken up in this connection beyond the fact that they have a superficial resemblance to *Receptaculites* and *Ischadites*, and have therefore been commonly placed alongside of these genera. It has, however, been demonstrated by Hinde that the latter are Hexactinellid Sponges, while it seems certain that the fossils here referred to—viz., *Pasceolus* and *Cyclocrinus*—are, at any rate, not referable to the *Porifera*, though their true position is quite problematical.

The genus *Pasceolus* (fig. 73, *a* and *b*) was created by Mr Billings for the reception of some curious Ordovician and Silurian fossils of an ovate or globular form, varying in size from the dimensions of a hazel-nut to those of an apple. The outer layer of the fossil consists of "small convex elevations, composed of a very thin minutely wrinkled layer, which is sometimes translucent" (Hinde). These surface elevations have the general aspect of being hexagonal or pentagonal plates, but there is not sufficient evidence that actual plates are present, and they may be, and probably are, only definitely limited areas of a common calcareous membrane. The inner, concave sides of these polygonal areas are directed *inwards*, towards the central cavity of the fossil (the cup-like plates of *Cyclocrinus* being turned *outwards*); and in well-preserved specimens they exhibit a minutely porous aspect. There is some evidence that the organism was provided with a peduncle of attachment, and in some species a lateral aperture has been described as present. By Mr Billings, it was at first supposed that *Pasceolus* might belong to the *Tunicata*, but this view was subsequently abandoned by him. By later palæontologists the genus has been doubtfully compared with *Receptaculites* or with the *Cystideans*, but its zoological affinities must in the meanwhile be regarded as entirely uncertain.

The genus *Cyclocrinus* was originally founded by Eichwald to include certain ovate or spherical fossils from the Ordovician rocks of Esthonia, which appear to have been free, and which have a thin, plated, external layer enclosing a large central cavity (fig. 73, *c-h*). The outer integument is calcareous, and presents externally the

aspect of being divided into a series of hexagonal or pentagonal areas of very regular form and size (fig. 73, *h*). Each of these areas has the form of a shallow cup-shaped depression, the lower or convex end of which is directed towards the interior of the fossil, and, according to Hinde, is perforated centrally by a small rounded aperture which leads into the central cavity of the organism. According, however, to Ferdinand Roemer, whose figures are here reproduced (fig. 73, *f* and *g*), each of these cup-like plates terminates internally

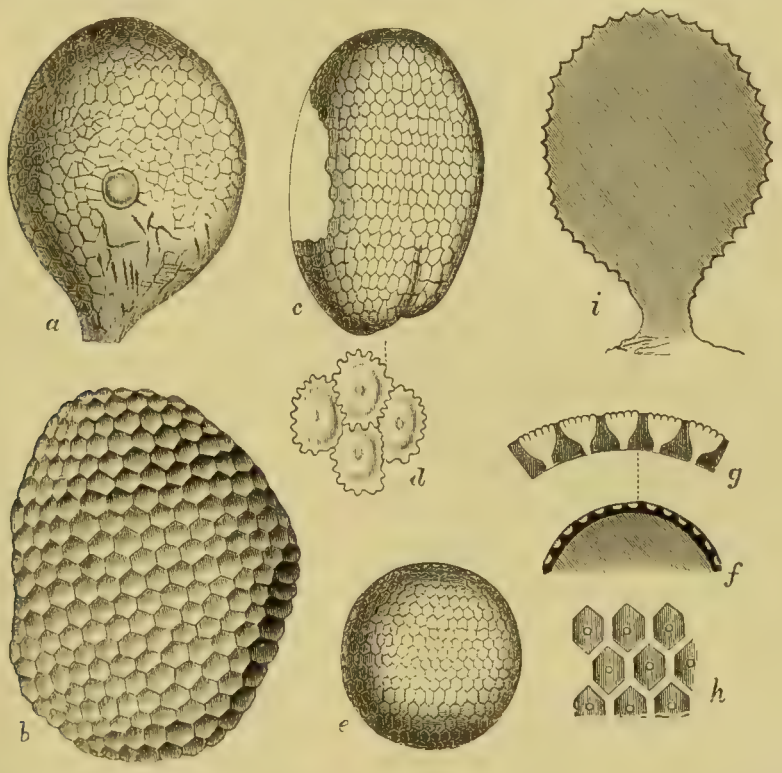


Fig. 73.—*a*, *Pasceolus Halli*, of the natural size (after Billings); *b*, *Pasceolus globosus*, of the natural size (after Billings); *c*, *Pasceolus* (?) *mellifiua*, of the natural size (after Salter); *d*, Four of the integumentary plates of the same, enlarged; *e*, *Cyclocrinus Spaskii*, of the natural size (after Ferd. Roemer); *f*, Part of a vertical section of the same; *g*, Part of the last, showing the structure of the integument, enlarged; *h*, Part of the mould of the inner surface, enlarged; *i*, Diagram of a vertical section of *Cyclocrinus* (*Nidulites*) *favus*, showing the form of the body and integumentary plates, and the supposed peduncle (original). All the specimens are from the Silurian, except *b*, which is from the Ordovician.

in a small pillar, and the genus is hence compared by this distinguished palæontologist with *Receptaculites*. Dr Hinde, on the other hand, does not recognise in *Cyclocrinus* any features of resemblance to *Receptaculites*, and considers that the genus is identical with *Nidulites*.

The present writer has not had the opportunity of studying the genus *Cyclocrinus*, and is therefore unable to express a positive

opinion as to its identity with *Nidulites*. It is clear, however, that the two are, at any rate, very closely related, if not absolutely identical. The name *Nidulites* was proposed by Salter for certain singular Silurian fossils (subsequently described by Eichwald under the name of *Mastopora*), which have the form of ovate, globular, or pyriform, hollow bodies, with a thin calcareous external wall, and probably attached to foreign bodies by a peduncle (fig. 73, *i*). The wall of *Nidulites* encloses a large central space, and is formed of short, wide, hexagonal calcareous tubes or cells, which are united together at their basal ends and also by their walls (fig. 74, A and B). The outer ends of these shallow tubes or cells are open, while the inner ends are closed by curved basal plates, the convexities of which are turned towards the central cavity of the organism. Moreover, the closed end of each cell is perforated by a small round central aperture (fig. 74, C), so that each cell communicates freely with the great internal cavity.

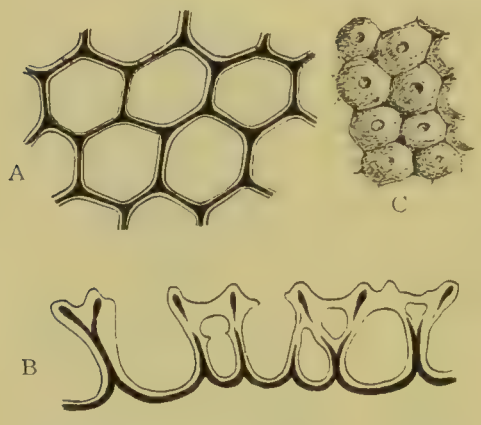


Fig. 74.—Structure of *Nidulites* (= *Mastopora*). A, Tangential section of the wall of *Nidulites*, showing the cup-like plates of the integument transversely divided, so as to give rise to a series of hexagonal cells, enlarged six times; B, Vertical section of the wall of the same, showing the short hexagonal cups or cells of the outer membrane longitudinally divided, similarly enlarged; C, A few of the cup-like plates of the wall, viewed internally and showing the central perforations in their bases, enlarged. From the Silurian rocks of the Island of Oesel. (Original.)

With regard to the affinities and systematic position of *Nidulites* and *Cyclocrinus*, it is not possible at present to give any decided opinion. There is no positive character exhibited by these singular fossils which would enable us to refer them definitely to any known division of the animal kingdom. The resemblances which they present to the *Receptaculitidæ* or to the *Cystideans* are quite superficial, and it is not even clear that they are genuinely related to the equally enigmatical genus *Pasceolus*. It may be pointed out, however, that there are some curious points of resemblance between *Nidulites* and *Cyclocrinus* on the one hand and certain of the Calcareous Algæ (*Siphoneæ verticillatæ*) on the other hand; and it does not seem impossible that these points of resemblance indicate a genuine relationship. If this conjecture should prove to be well founded, these singular fossils may ultimately find a resting-place in the vegetable kingdom.

LITERATURE.

I. Archæocyathinæ.

1. "Palæozoic Fossils of Canada," vol. i., 1861-65. Billings.
2. "The Dawn of Life" (p. 151). Dawson. 1875.
3. "Second Contribution to the Studies on the Cambrian Faunas of North America." 'Bull. U.S. Geol. Survey,' No. 30. 1886. Walcott.
4. "Die Versteinerungen des Cambrischen Schichtensystems der Insel Sardinien." 1886. Bornemann.
5. "On Archæocyathus, Billings, and on other Genera allied to or associated with it, from the Cambrian Strata of North America, Spain, Sardinia, and Scotland." 'Quart. Journ. Geol. Soc.,' vol. xlv. 1889. Hinde.

II. Pasceolus, Nidulites, and Cyclocrinus.

1. "Palæozoic Fossils of Canada," vol. i. 1861-65. Billings. (Pasceolus.)
2. "Nidulites." 'Quart. Journ. Geol. Soc.,' vol. vii., 1851. Salter.
3. "Cyclocrinus." 'Lethæa Rossica.' 1860. Eichwald.
4. "Nidulites." 'Monograph of the Silurian Fossils of Girvan.' 1878. Nicholson and Etheridge, jun.
5. "Lethæa Palæozoica." 1880. Ferd. Roemer.
6. "On the Structure and Affinities of the Family of the Receptaculitidæ." 'Quart. Journ. Geol. Soc.' 1884. Hinde.

CHAPTER XIII.

SUB-KINGDOM III.—CŒLENTERATA.

GENERAL CHARACTERS AND DIVISIONS OF CŒLENTERATES—HYDROZOA—DIVISIONS OF HYDROZOA.

THE sub-kingdom *Cœlenterata* (Frey and Leuckart) may be considered as a modern representative of the *Radiata* of Cuvier. From the *Radiata*, however, the *Echinodermata* and *Rotifera* have been removed, the entire sub-kingdom of the *Protozoa* has been taken away, and the *Polyzoa* have been relegated to a place near the *Mollusca*. Deducting these groups from the old *Radiata*, the residue, comprising most of the animals commonly known as Polypes or Zoophytes, remains to constitute the modern *Cœlenterata*.

The *Cœlenterata* may be defined as *radially symmetrical animals, in which the mouth opens into a simple or variously divided space ("cœlenteric cavity"), which acts as an alimentary cavity, and which may or may not be divided into two portions, of which one forms a rudimentary digestive tube. The body-wall consists of two fundamental layers ("ectoderm" and "endoderm"), between which an intermediate layer ("mesoderm") is usually developed. Peculiar urticating organs, or "thread-cells," are present. The nervous system is sometimes specialised, sometimes diffused; but no vascular organs are developed. Reproductive organs are invariably present at some period or another of life, though asexual reproduction is also very general.*

The sub-kingdom *Cœlenterata* is divided into the two great primary divisions or classes of the *Hydrozoa* and *Actinozoa*, and the following table indicates the main subdivisions of these :—

TABLE OF THE DIVISIONS OF THE CŒLENTERATA.

CLASS I.—HYDROZOA.

Sub-class 1. HYDROIDA (Hydroid Zoophytes).
a. Hydrida.—Ex. Hydra.
b. Corynida.—Ex. Tubularia, Hydractinia.

c. Thecaphora.—Ex. Sertularia, Campanularia.
d. Trachymedusæ.—Ex. Trachynema.
Sub-class 2. SIPHONOPHORA (Oceanic Hydrozoa).
a. Calycophoridæ.—Ex. Diphyes.
b. Physophoridæ.—Ex. Physalia.
Sub-class 3. LUCERNARIDA (Sea-blubbers).
a. Calycozoa.—Ex. Lucernaria.
b. Acraspeda (*Discophora*).—*Ex.* Aurelia, Rhizostoma.
Sub-class 4. GRAPTOLITOIDEA (Graptolites).
Sub-class 5. HYDROCORALLINÆ (Hydrocorallines).
a. Milleporidæ.—Ex. Millepora.
b. Stylasteridæ.—Ex. Stylaster.
Sub-class 6. STROMATOPOROIDEA (Stromatoporoids).

CLASS II.—ACTINOZOA.

Order 1. ZOANTHARIA.—*Ex.* Sea-Anemones (*Actinidæ*) Corals (*Madreporaria*).
Order 2. ALCYONARIA.—*Ex.* Sea-pens (*Pennatulidæ*), Red Coral (*Corallium*), Organ-pipe Coral (*Tubipora*).
Order 3. CTENOPHORA.—*Ex.* Venus's Girdle (*Cestum*).

As regards their general *distribution in time*, the earliest known remains of Cœlenterates appear in the Upper Cambrian rocks, where the sub-kingdom is represented by ancient types of the *Hydrozoa*.



Fig. 75.—Diagrammatic vertical section of a Sea-anemone. *a*, Mouth; *s*, Gullet; *b*, Body-cavity; *c c*, Convoluted cords ("craspeda") forming the free edges of the mesentery (*m*); *t t*, Tentacles; *o*, Reproductive organ contained within the mesentery. The ectoderm (*e*) is indicated by the broad external line, the endoderm (*e'*) by the thin line, and the space between that and the ectoderm represents the mesoderm.

In the Ordovician rocks we find the two great classes of the *Hydrozoa* and the *Actinozoa* thoroughly differentiated, and existing under many and varied types, a fact which would lead us to assign a very high antiquity to the early progenitors of this series

of animals. From the beginning of the Ordovician rocks onwards, the Cœlenterates are very abundant and important as fossils, the large groups of the *Graptolitoidea* and *Stromatoporoidea* being wholly extinct, and having no close relatives now in existence. Owing to the fact, however, that other large groups (such as the Lucernarians, the Oceanic Hydrozoa, and the Ctenophora) are almost or altogether without hard parts, and therefore only capable of preservation in the fossil condition under very exceptional circumstances, the geological history of the sub-kingdom is very imperfect.

Class I.—Hydrozoa.

The class of the *Hydrozoa* comprises those Cœlenterates *in which the walls of the body enclose a simple undivided cavity* (*the "cœlenteric cavity"*), *which acts both as a body-cavity and a digestive cavity. An œsophageal tube is not developed; but the upper end of the alimentary*

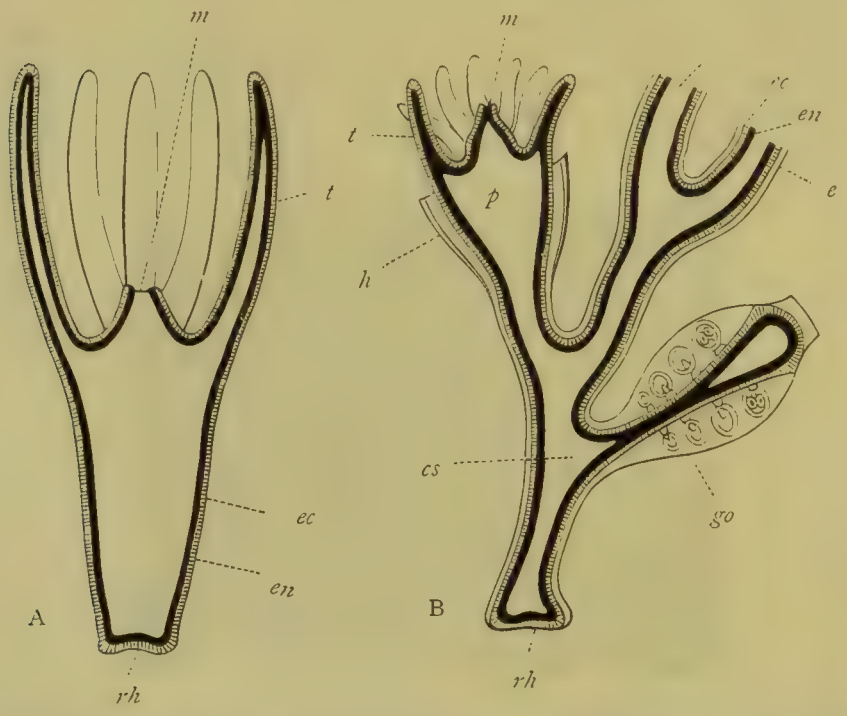


Fig. 76.—A, Diagram of *Hydra*, vertically bisected, and greatly magnified; B, Diagram to show the structure of a compound Hydrozoön (*Sertularia*). *ec*, Ectoderm; *en*, Endoderm; *m*, Mouth, opening into the cœlenteric space or body-cavity; *t*, Tentacle; *p*, Nutritive polypite; *go*, Reproductive bud or "gonophore," consisting of a capsule enclosing a central axis to which reproductive polypites are attached; *cs*, Cœnosarc; *rh*, Hydrorhiza; *pe*, Periderm; *h*, Hydrotheca.

tract may be prolonged into radiating canals united by a peripheral ring. The reproductive organs are external buds, and are often developed in specially modified zoöids (fig. 76).

The simplest type of the *Hydrozoa* is the genus *Hydra*, comprising the Fresh-water Polypes, in which the organism consists of a single tubular or cylindrical "polypite" (fig. 76), furnished at its base or "proximal" extremity with a disc-like sucker or "hydro-



Fig. 77.—A, Part of the colony of *Bougainvillea muscus*, one of the composite Hydrozoa, of the natural size. B, Part of the same enlarged; *p*, A polypite fully expanded; *m*, An incompletely developed medusiform bud; *m'*, A more completely developed medusiform bud; *f*, Cœnosarc with its investing periderm and central canal. C, A free medusiform gonophore of the same; *n*, Gonocalyx; *p*, Manubrium; *c*, One of the radiating gastro-vascular canals; *o*, Ocellus; *v*, Velum; *t*, Tentacle. (After Allman.)

rhiza," by which it can attach itself to foreign bodies. At the opposite or "distal" end of the body is the opening of the mouth (fig. 76, *m*), surrounded by a variable number of hollow, extensile and tactile processes or "tentacles." The body-wall is composed of

an outer and inner membrane, known respectively as the "ectoderm" and "endoderm," and no hard external layer is produced. The mouth opens into a cylindrical body-cavity or "cœlenteric space," which runs the whole length of the body, and is completely undivided, no gullet being developed. There are, therefore, no radiating membranous partitions corresponding with the "mesenteries" of the *Actinozoa*. The animal can produce buds, which become developed into new "polypites," but these do not remain attached to the parent polypite, and the organism does not, therefore, become composite. Moreover, at certain seasons, the animal develops true reproductive organs, which have the form of external buds. These discharge the reproductive elements by rupture of their walls, but are not themselves separated from the organism.

The ovum in all the *Hydrozoa* gives rise to a "polypite" similar in structure to the entire organism in *Hydra;* but the primordial polypite is often endowed with the power of throwing out buds which remain, some or all of them, permanently united with the original "zoöid." In this way is produced a composite organism (fig. 76, B, and fig. 77), consisting of a greater or smaller number of zoöids or "polypites," united by a common fleshy stem or "cœnosarc." Very generally, the zoöids become differentiated into two sets, which differ in structure and in the part they play in the life of the colony. In the one series the zoöids constitute the ordinary nutritive "polypites" of the colony (fig. 77, *p*), and are concerned with supplying food to the organism. In the other series the zoöids—now spoken of by the general name of the "gonophores"—have a reproductive function, and are concerned with the production of the generative elements. These generative zoöids or "gonophores" may remain permanently attached to the parent colony (fig. 76, B), or they may become much modified and may become detached to lead a free existence (fig. 77). In this latter case, the detached generative zoöids usually present themselves in the form of "Jelly-fishes" or "Medusoids."

The colonies of the composite *Hydrozoa* are sometimes free, the proximal end of the cœnosarc not being adapted for fixation (as in the *Siphonophora* and the *Graptolitoidea* proper). In other cases the colony is attached to some foreign body by a modified proximal extremity or "hydrorhiza" (fig. 76, *rh*).

In a number of the composite *Hydrozoa* no hard structures in the shape of an external skeleton are developed. In many cases, however, the ectoderm secretes a firm horny outer layer or "periderm" (fig. 76, *pe*), which may cover the cœnosarc only (as in *Bougainvillea*, fig. 77), or may be extended into little cups or "hydrothecæ" within which the individual polypites are contained. When "hydrothecæ" are present, the body of the polypite is contained within the cup, and the distal extremity, with the mouth and tentacles,

can be protruded from the terminal opening or "aperture" of the hydrotheca (fig. 76 B, *h*). In some cases, not only are the nutritive polypites protected within "hydrothecæ," but the generative buds or gonophores are also provided with a horny or chitinous covering, constituting what are known as "gonangia." Lastly, in the group of the Hydrocorallines, and in a few other cases, the colony has the power of secreting carbonate of lime, and thus of giving rise to a calcareous skeleton, which in many cases is superficially similar to the "corallum" of certain of the *Actinozoa*.

With regard to the distribution of the *Hydrozoa* in *space*, the great majority of the organisms included under this head are marine, but in a few cases (*e.g.*, *Hydra*) the organism is found in fresh water. As to the general distribution of the class in *time*, the Fresh-water Polypes (*Hydrida*), the Oceanic Hydrozoa (*Calycophoridæ* and *Physophoridæ*), and the *Calycozoa* (*Lucernaria*, &c.) have left no traces of their past existence, as might have been anticipated from their want of hard parts. The *Trachymedusæ* and *Acraspeda* (Jelly-fishes and Sea-blubbers) are equally destitute of hard structures, and their absence from the palæontological record might have been confidently predicted. Under favourable circumstances, however, these soft-bodied organisms are capable of leaving impressions in soft mud or sand, by which their past existence may be determined; and such impressions have been recognised in deposits even as ancient as the Cambrian. The great group of the *Graptolitoidea* is not only entirely extinct, but is wholly restricted to the older Palæozoic rocks. The equally great group of the *Stromatoporoidea* is also extinct, and is principally confined to the earlier Palæozoic deposits, though fossils which are probably referable here are also found in the Mesozoic rocks. The *Corynida* and *Thecaphora*, both largely represented in recent seas, have left but few and imperfectly connected traces of their existence in past time; and some of the forms usually referred to these orders, and especially the more ancient ones, are of more or less dubious affinities. The recent genus *Hydractinia*, among the *Corynida*, occurs, however, in rocks as old as the Cretaceous. Lastly, the existing group of the Hydrocorallines is represented by fossil forms, which begin as early as the Trias.

In the following more detailed summary of the main divisions of the *Hydrozoa* and of their principal fossil forms, those groups which, as above mentioned, are not known to be represented in past time are left out of account.

Sub-class Hydroida.

The sub-class of the "Hydroid Zoophytes" comprises a large number of *Hydrozoa* in which the organism is attached, or is cap-

able of attachment, to foreign bodies by means of a modified proximal extremity or "hydrorhiza." A few of the types included in this sub-class are simple (*e.g.*, *Hydra*), but the organism consists



Fig. 78.—Recent Corynida. A, Portion of the colony of *Perigonimus minutus*, with polypites and reproductive buds, enlarged about 25 diameters; B, A single polypite of *Bimeria vestita*, greatly enlarged, showing the extension of the polypary upon the bases of the tentacles. (After Allman.)

typically of numerous simple polypites united by a branched "cœnosarc," and forming a plant-like or encrusting colony. Very

usually, the colony develops hard structures ("polypary" or "cœnosteum"), which may have the form of an external chitinous layer, or, in some instances, is composed of carbonate of lime. Reproduction takes place by fixed generative buds, or by the development of free reproductive zoöids ("gonophores").

Of the orders of the Hydroid Zoophytes, the only three which have fossil representatives are the *Corynida*, the *Thecaphora*, and the *Trachymedusæ*.

Order 1. Corynida.—The "Tubularian Zoophytes" or *Corynida* are mostly composite, forming more or less plant-like, or encrusting colonies, fixed to foreign objects proximally, and usually furnished with a skeleton or "polypary." The skeleton is mostly in the form of a chitinous investment, which encloses the cœnosarc (fig. 78, A), but which is not developed into definite cups or "hydrothecæ" for the reception of the individual polypites. In some cases, however, the skeleton consists of zoöidal tubes, in which the polypites were lodged, united by a general clathrate or tubulated cœnosarcal skeleton, as in the genus *Hydractinia* and its fossil allies. In the living genus *Bimeria*, also, the polypary forms an investment for the polypites, and is even prolonged upwards as far as the bases of the tentacles fig. 78, B). Though the skeleton of the *Corynida* is usually chitinous in composition, it is occasionally calcareous (as in some species of *Hydractinia* and in the genus *Parkeria*).

There are many recent types of the *Corynida*, such as the common Pipe-corallines (*Tubularia*), which, from the nature of their skeleton, might quite well have been preserved in the fossil condition. The only recent genus, however, of which any fossil representatives are known is *Hydractinia*, the colonies of which are well known as forming crust-like investments upon shells. The species of *Hydractinia* form chitinous—or rarely calcareous—crusts upon the exterior of the shells of Gastropods (fig. 79, A), the shell thus affected being often ultimately more or less largely dissolved away, and replaced by the substance of the parasite. The skeleton of *Hydractinia*, when fully grown, consists of numerous close-set vertical columns ("radial pillars," fig. 79, D *p*), which are united at irregular intervals by horizontal "laminæ," the number of these, and the consequent thickness of the crust, varying in different individuals or in different species. The successive "laminæ" are separated by narrow intervals or "interlaminar spaces" (fig. 79, *i*), which are broken into irregular chambers by the ascending "radial pillars." The "laminæ" themselves are not continuous membranes, but are formed by the anastomosis of numerous horizontal connecting-processes or "arms" (fig. 79, E *c*), which spring from the radial pillars at tolerably regular intervals. The "laminæ" are thus more or less cribriform, the apertures in their substance serving as tubes for the

zoöids of the colony, while the interlaminar spaces are filled with the soft cœnosarc. The surface of the skeleton is covered with projecting wart-like tubercles, interspersed with larger pointed spines (fig. 79, B and C), these being really the upper projecting ends of the "radial pillars." The surface also shows (fig. 79, B) the rounded pores which lodged the zoöids, together with singular branched grooves or open canals, which apparently serve for the lodgment of processes of the cœnosarc. In the living species of

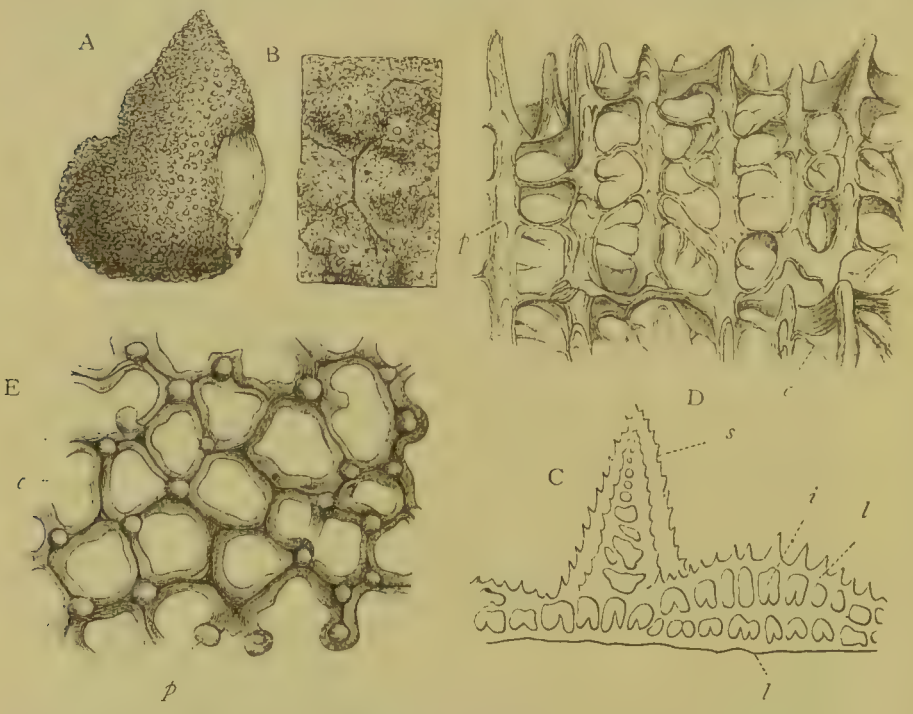


Fig. 79.—A, A colony of *Hydractinia pliocæna*, attached to the shell of a Gastropod, of the natural size, Pliocene. B, Portion of the surface of the same enlarged, showing wart-like prominences, branched cœnosarcal canals, and minute circular zoöidal apertures. C, Vertical section of the crust of the recent *Hydractinia echinata*, showing surface-tubercles and spines (*s*). The successive laminæ of the skeleton (*l*, *l*) are separated by "interlaminar spaces" (*i*) which are broken up into irregular chambers by "radial pillars." D, Vertical section of the crust of *Hydractinia echinata*, greatly enlarged, showing its composition out of vertical processes ("radial pillars") united by horizontal bars or "arms" (*c*). E, Horizontal section of the same, showing the pillars (*p*) and their connecting-processes (*c*), greatly enlarged. (After Allman, Carter, and the Author.)

Hydractinia the organism consists of the general crust-like cœnosarc, and of a large number of "polypites" emitted from the surface of the same. Many of these polypites have mouths and tentacles, and are devoted to the nutrition of the colony; others are non-tentaculate, and carry sac-like generative buds, which are not detached from the parent-colony; while others form long spirally coiled filaments, apparently intended for defensive purposes.

The recent species of *Hydractinia* are all marine, and the skeleton is in general composed of chitine; but in an African species, de-

scribed by Mr Carter, the skeleton is calcareous. The earliest known fossil forms of *Hydractinia* appear in the Cretaceous rocks, and a number of Tertiary forms are known. In the *Hydractinia circumvestiens* of the Pliocene Tertiary (which is probably identical with the *H. pliocæna* of Dr Allman), the skeleton is calcareous, and forms thick crusts upon the shells of Gastropods (fig. 79, A). The genera *Thalaminia* (Jurassic and Cretaceous) and *Sphæractinia* (Jurassic) have been founded by Steinmann for forms apparently allied to *Hydractinia*, and it is not impossible that the Jurassic genus *Ellipsactinia*, of the same author, should likewise be placed here.

In many respects related to *Hydractinia* is the singular Mesozoic genus *Parkeria*, best known by the *Parkeria sphærica* of the Greensand of Cambridge. The organism in *Parkeria sphærica* (fig. 80) is globular in form, and varies in diameter from a quarter of an inch or less up to more than two inches, the surface being often nodulated or covered with small rounded or elongated elevations. The skeleton must have been free in its adult condition, as a rule at any rate; but in many cases it grew round some foreign body, such as a fragment of shell. As to its chemical composition, there is no sufficient reason to doubt that the skeleton was originally composed of carbonate of lime, though many specimens are now found to be more or less largely phosphatised. As regards its minute structure, the skeleton is found, when examined microscopically by means of thin sections, to be composed of a characteristic minutely tubulated tissue, the tubules of which are radial in arrangement. This tubulated tissue is built up into a set of radiating columns ("radial pillars," fig. 81, *p*) and a series of concentrically disposed lamellæ, the latter being separated by interspaces ("interlaminar spaces"), which are broken up into irregular "chamberlets" (fig. 81, *c*). The tubulated tissue of the "radial pillars" is traversed by a variable number of comparatively wide, circular or oval tubes, which open upon the surface, or into the chamberlets—each successive row of chamberlets having at one time formed the surface of the skeleton—and which may be regarded as having lodged the nutritive polypites of the colony. Upon the whole, *Parkeria* may be regarded as representing an aberrant type of the *Hydractiniidæ*, but the genus has also relations to the Hydrocorallines. The little spheroidal fossils

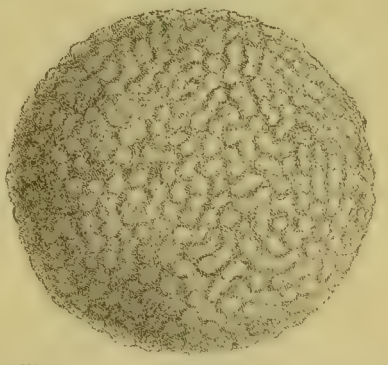


Fig. 80.—A large specimen of *Parkeria sphærica*, from the Upper Greensand of Cambridge, of the natural size. (Original.)

from the Chalk which have been placed in the genus *Porosphæra* have often been regarded as related to *Parkeria*, but their minute structure would rather support their being placed among the Sponges.

In connection with the preceding, a few words may be said with regard to the singular genera *Mitcheldeania* and *Solenopora*, which are of doubtful affinities, though the balance of evidence is in favour of referring them to the *Hydrozoa*. The genus *Mitcheldeania* comprises small



Fig. 81.—Vertical section across the centre of a specimen of *Parkeria*, enlarged twice. *p*, One of the radial pillars; *c*, One of the chamberlets. (Original.)

spheroidal fossils rarely reaching half an inch in diameter, which sometimes occur in such vast quantities as to give rise to actual beds of the Carboniferous Limestone (fig. 82). When examined microscopically, the skeleton of *Mitcheldeania* is found to be formed of radiating capillary tubes, which are disposed in concentric strata, and have a diameter of from $\frac{1}{25}$ to $\frac{1}{15}$ of a millimetre. These tubes have porous walls, and are united by a still more minutely tubulated tissue; but the structure of the organism is too complex to be advantageously discussed here.

The genus *Solenopora* comprises calcareous organisms of varying size, usually ranging from the dimensions of a pea up to those of an

orange, and of irregular shape (fig. 83, A). Examined microscopically, the organism in *Solenopora* is found to be wholly composed of radiating

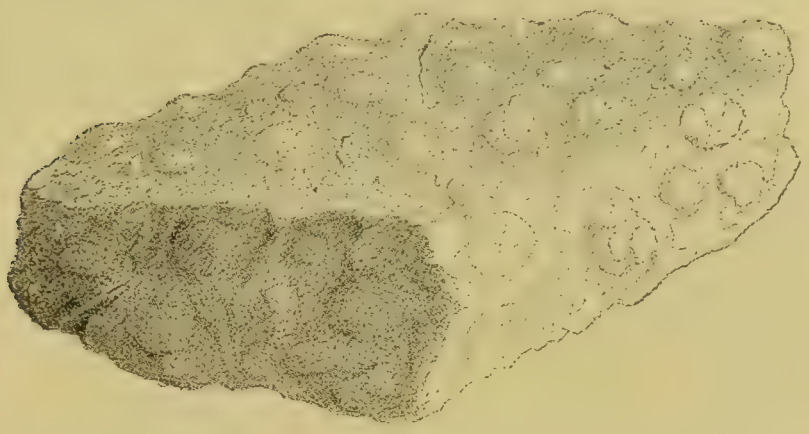


Fig. 82.—A fragment of limestone rom the Lower Carboniferous Series of the south of Scotland, largely composed of *Mitcheldeania gregaria*, of the natural size. (Original.)

capillary tubes, arranged in concentric strata. The tubes (fig. 83, D) vary from $\frac{1}{12}$ to $\frac{1}{20}$ millimetre in size, and are in direct contact throughout, no interstitial tissue of any kind being developed. The tubes are irregular

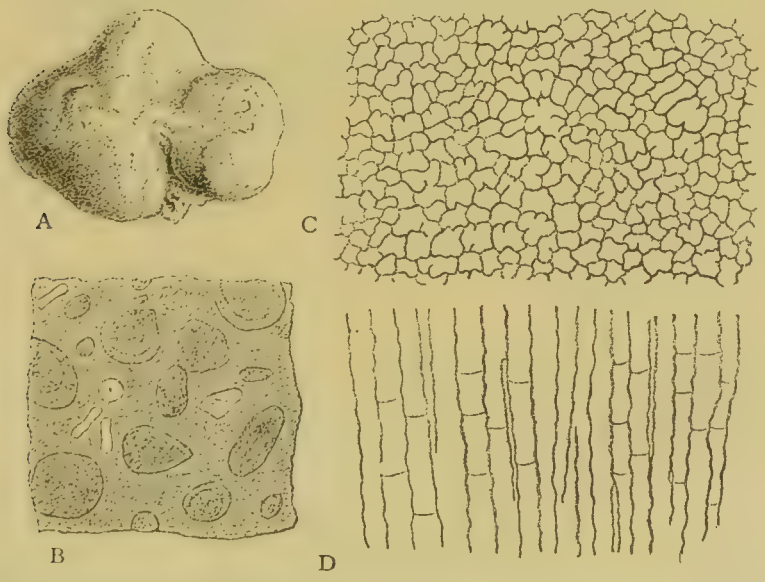


Fig 83.—A, A small specimen of *Solenopora compacta*, Billings, from the Ordovician rocks of Saak, Esthonia, of the natural size; B, Surface of a piece of limestone largely made up of small specimens of the same, from the same locality, of the natural size; C, Tangential section of the same, enlarged about 35 times; D, Vertical section of the same, similarly enlarged. (Original.)

in form, with thin, often undulated walls, which are not pierced by any apertures or pores, but are often crossed by more or fewer transverse

partitions or "tabulæ" (fig. 83, D). Very commonly the tubes exhibit more or fewer inwardly directed partitions, which extend to a greater or less distance into the cavity of the tube, and are the result of the cleavage or "fission" of the tubes. The species of *Solenopora* are entirely confined to the Ordovician rocks, and sometimes occur in such profusion as to give rise to beds of limestone. The best known species (viz., *S. compacta*) has been recognised in the Ordovician limestones of Russia, Britain, the United States, and Canada.

Both *Mitcheldeania* and *Solenopora* are remarkable for the extraordinary minuteness of their component tubes, and in this respect they differ from all known Cœlenterates. Apart from this feature, they present in their structure a general resemblance to forms like *Parkeria*, and they



Fig. 84.—Sertularida. A, Portion of the colony of *Diphasia* (*Sertularia*) *tamarisca*, of the natural size, showing hydrothecæ and female ovarian capsules (gonangia). B and C, Portions of different branches of the same, enlarged: *h*, Hydrothecæ; *a*, Male gonangium; *g*, Female gonangium. (After Hincks.)

may therefore be provisionally placed among the Hydroid Zoophytes. In some points, however, the genus *Mitcheldeania* would appear to be rather related to the Hydrocorallines.

Among the other forms which have been referred to the *Corynida* are the genera *Corynoides* and *Palæocoryne*. The former of these may, perhaps, be best regarded as an abnormal type of the *Graptolitoidea*, and will be alluded to in speaking of these organisms. The genus *Palæocoryne*, on the other hand, is founded upon structures which belong to the fronds of certain of the *Fenestellidæ*, and it will therefore be treated of in dealing with the *Polyzoa*.

Order 2. Thecaphora.—This order includes the Sea-firs and their allies (*Sertularida* and *Campanularida*), in which the organism is fixed, and consists of a more or less plant-like colony (fig. 84, A), composed of numerous polypites united by a common stem or "cœnosarc." The cœnosarc usually consists of a main stem or "hydrocaulus," with many branches, and it is fixed to foreign bodies by an adherent base or "hydrorhiza." The colony produces a strong corneous or chitinous outer investment (the "periderm" or "polypary"), which not only invests the cœnosarc, but is also prolonged into cup-like receptacles, which enclose the individual polypites, and are known as the "hydrothecæ." The reproductive zoöids ("gonophores") are either set free as Jelly-fishes (as in the Campanularians generally), or are developed within urn-like receptacles ("gonangia" or "gonothecæ"), which are of larger size than

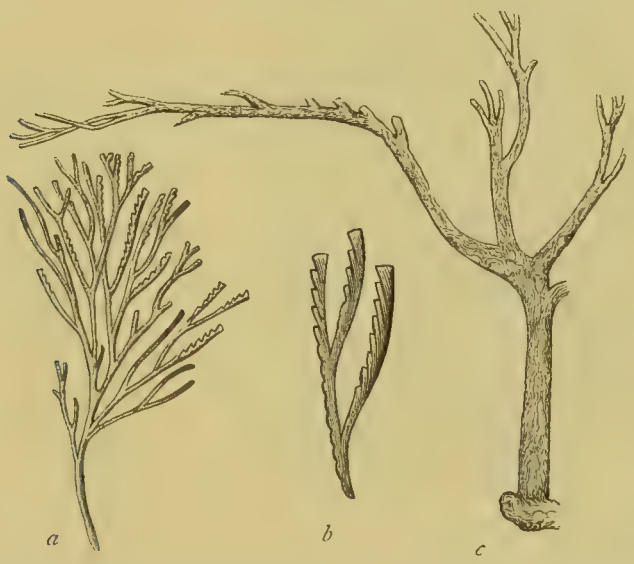


Fig. 85.—*Dendrograptus Hallianus*. *a*, Portion of the frond, natural size; *b*, Portion of a branch, enlarged; *c*, The footstalk and some of the principal branches, natural size. Upper Cambrian (Potsdam Sandstone). (After Hall.)

the ordinary hydrothecæ (fig. 84, B and C). In this latter case, the reproductive zoöids are not liberated from the parent colony as independent organisms. In the typical Sertularians, the hydrothecæ spring directly from the sides of the cœnosarc and are not supported on stems, and they may be biserial (as in *Sertularia* and *Diphasia*, fig. 84, A), or they may, as in *Plumularia* and its allies, be developed on one side only of the divisions of the cœnosarc. On the other hand, in the Campanularians the polypites are stalked and terminal, each being placed at the end of a division of the cœnosarc.

The existing *Thecaphora* are not only very abundant and very

widely represented in recent seas, but they possess a chitinous polypary which seems to be quite as well suited for preservation in fine-grained sediments as is that of the Graptolites. It is therefore a matter difficult of explanation that, except in late Quaternary deposits, no trace of an absolutely undoubted Sertularian or Campanularian, similar to the ordinary existing forms of the order, has been as yet discovered. On the other hand, the ancient Palæozic deposits have yielded the remains of various extinct organisms, which have often been referred to the *Graptolitoidea*, but which, with greater probability, may be regarded as early types of the *Thecaphora*. One of the most interesting of these is the Cambrian and Ordovician genus *Dendrograptus*, in which the organism had the form of a spreading

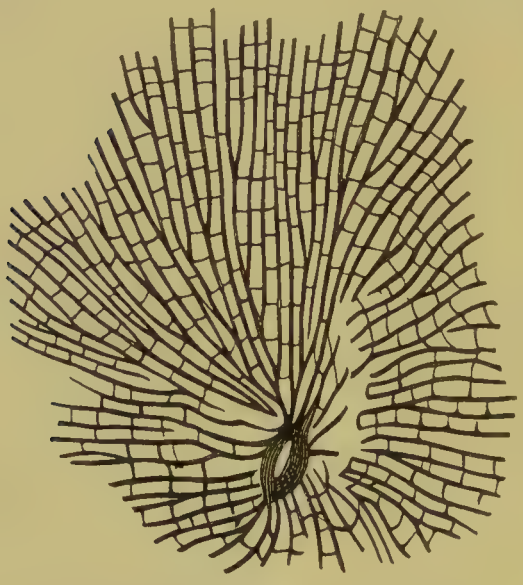


Fig. 86.—*Dictyonema retiforme*, Hall. Silurian (Niagara Group), United States. (After Hall.)



Fig. 87.—A branch of *Ptilograptus plumosus*, Hall. Enlarged. Ordovician (Quebec Group), Canada. (After Hall.)

and branched frond, furnished with a strong footstalk (fig. 85), by which it was probably attached to some foreign body. The branchlets carry upon one side a series of little chitinous cups or "hydrothecæ" ("cellules"), which agree with the similar structures of the Graptolites in partially overlapping one another.

In *Dictyonema* (fig. 86) we have organisms resembling *Dendrograptus* in many respects, but not possessing any footstalk. The frond is branched and plant-like, and is fan-shaped or funnel-shaped in form. It is not certainly known whether the organism was attached by its base or not; but there is the strongest probability in favour of its having been fixed. The branches radiate from the base, running nearly parallel with one another, and often bifurcating. They are united to one another at short intervals by numerous, irregular,

slender, transverse processes or dissepiments, and they bear small horny cups or "hydrothecæ" ("cellules") like those of the Graptolites. *Dictyonema* ranges from the Upper Cambrian to the Middle Devonian. The genus bears a close superficial resemblance to the *Fenestellæ* or Lace-corals (belonging to the *Polyzoa*); but the latter have a calcareous skeleton, and have no "hydrothecæ." Besides the above-mentioned genera, *Callograptus* and *Ptilograptus* (fig. 87) may with great probability be referred to the *Thecaphora;* as may, perhaps, be the obscure fossils *Buthograptus* and *Thamnograptus*. All these genera are found in the Ordovician or Silurian rocks.

Oldhamia.—The singular structures described under the genus *Oldhamia* may be noticed here, as they have been referred to the *Hydrozoa;* though their true nature is altogether uncertain. *Oldhamia* occurs in certain green and purple grits of Lower Cambrian age, at Bray Head, in Wicklow, Ireland, where the supposed fronds are found in great abundance, matted together, and spreading over the surfaces of the strata. A form of *Oldhamia* is also said to occur plentifully in the Potsdam Sandstone (Upper Cambrian) of Wisconsin, in North America, and still another form has been described by Barrois from the Cambrian rocks of the Pyrenees. *Oldhamia antiqua*, the commonest form, consists of a central thread-like axis from which spring bundles or umbels of short radiating branches (fig. 88), at regular intervals; whereas in the so-called *Oldhamia radiata* the branches radiate from a central point in all directions. *Oldhamia* has been variously referred to the Sertularian Zoophytes, to the *Polyzoa*, and to the *Algæ*. It has not, however, been as yet satisfactorily shown that *Oldhamia* is truly organic, and it is quite possible that the structure so called is the result of purely inorganic agencies. If really organic, it would seem more than probable that *Oldhamia* is referable to the vegetable kingdom, and that it belongs to the *Algæ*. This is the view held by Barrois, who compares *Oldhamia* with some of the types of *Algæ* which are placed in the family of the *Dasycladeæ*.



Fig. 88.—*Oldhamia antiqua*, natural size (after Salter). Cambrian.

Order 3. Trachymedusæ. — The *Trachymedusæ* constitute a peculiar group of the "Jelly-fishes," which agree with all the organisms grouped under this popular designation in the possession of a gelatinous swimming-bell, from the under side of which is suspended a single "polypite." From the margin of the swimming-bell depend

solid tentacular processes, and the substance of the bell is traversed by simple radiating canals which communicate above with the gastric cavity of the polypite. The reproductive organs are developed in the course of the radiating canals of the disc, and the embryo is developed directly into the adult form, without the intervention of an intermediate fixed and sexless stage.

Though wholly devoid of hard structures, the *Trachymedusæ*, as will be more fully pointed out in dealing with the *Acraspeda*, are capable of leaving traces of their past existence in the form of impressions left by their stranded bodies in fine mud. Impressions of this nature have been recognised in the fine-grained lithographic limestone (Jurassic) of Solenhofen, in Bavaria, and have been referred to the genera *Palægina* and *Trachynemites*, representing respectively the two existing groups of the *Æginidæ* and *Trachynemidæ*.

Sub-class Lucernarida.

The division of the *Lucernarida* comprises a large number of recent *Hydrozoa* in which the base of the organism is developed into a disc-shaped or cup-like structure (the "umbrella"), in the walls of which the reproductive organs are developed, and which carries on its concave side a single, more or less modified "polypite." The "Jelly-fish" thus constituted may develop itself directly, or it may be only the generative form of a minute fixed organism ("Hydra-tuba"), from which it is produced by fission.

The peculiar group of Lucernarians (*Calycozoa*) of which *Lucernaria* itself is the type, is wholly unrepresented by fossil forms, and needs no further consideration here. On the other hand, the group of the *Acraspeda*—or, as it is often called, *Discophora*—has left various traces of its past existence, and is in many ways of palæontological interest. The group of the *Acraspeda* comprises most of the larger organisms which are usually spoken of as "Jelly-fishes," though the structures so called are for the most part merely the generative zoöids produced by a minute sexless Lucernarian. Such a Jelly-fish (as, for example, the recent *Aurelia*) consists of a great gelatinous swimming-bell or "umbrella," from the under side of which hangs a single polypite, the structure of which is greatly modified in the *Rhizostomidæ*. The swimming-bell is traversed by a complex system of canals, connected superiorly with the gastric cavity of the polypite (fig. 89), and its margin usually carries more or fewer "tentacles," which are often of great length. The mouth of the polypite is extended into fringed or lobed processes, often of great length (fig. 89, *l*). Lastly, the reproductive organs are in the form of four folded bands, which project into four special cavities (the "sub-genital pouches") in the floor of the gastric cavity.

The Acraspedote Jelly-fishes are wholly marine, and are often of very large size. They usually swim near the surface, but they have been observed to crawl about on the sea-bottom in shallow water, and they have also been seen to lie at the bottom with the base of the umbrella turned downwards and the tentacles directed upwards. Though they possess no hard structures, and though their tissues are saturated with water, and therefore singularly perishable, they are nevertheless capable of producing impressions in sand or mud by which their past existence, and even their form, may be determined.

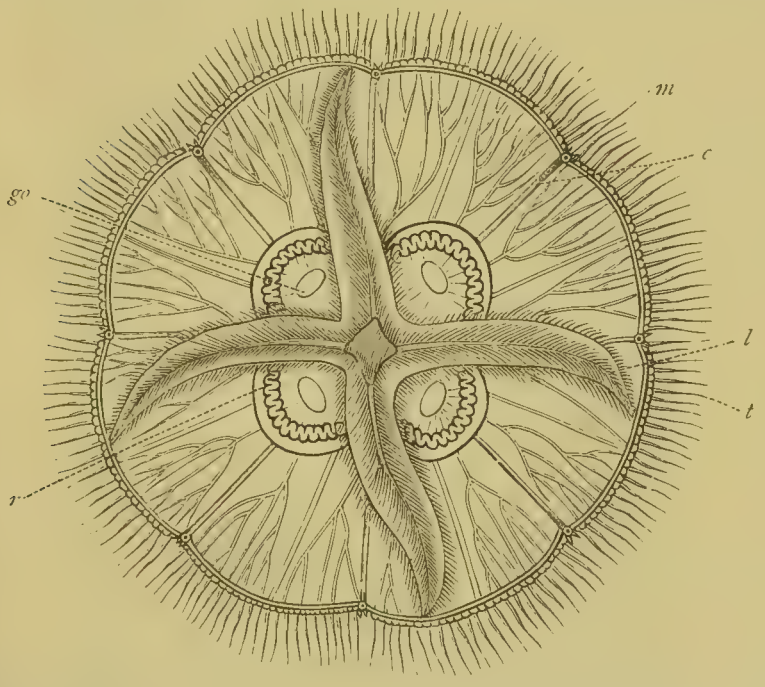


Fig. 89.—Under side of the umbrella of *Aurelia aurita*, one of the Acraspedote Medusæ, reduced in size. *l*, One of the four oral lobes, in the centre of which is placed the mouth; *t*, Tentacles attached to the margin of the umbrella; *c*, One of the radiating canals of the umbrella; *m*, Sense-organ; *r*, Reproductive organ, projecting into a "sub-genital pouch" (*go*). (After Claus and Sedgwick.)

The markings by which the former existence of Jelly-fishes may be recognised are of different kinds in different cases. In one group of cases the body of the Jelly-fish has fallen after death upon the fine mud of the sea-bottom, or has been thrown up on the shore, and an impression representing the swimming-bell, and in some cases the tentacles, of the animal, has thus been formed in the soft sediment. Upon impressions of this nature in the lithographic slates (Jurassic) of Solenhofen, Haeckel has founded various genera. Some of these, as previously noted, are believed to belong to the group of the *Trachymedusæ;* but others, such as *Rhizostomites* (fig. 90) and

Hexarhizites, are considered as referable to the *Acraspeda*, and to be related to such living types as *Rhizostoma*.

Of a somewhat more questionable nature are the singular bodies from the Cambrian rocks of Sweden, to which Nathorst has given the name of *Medusites*. These bodies are usually in the form of four-rayed or five-rayed stars, or have the shape of four-sided or five-sided pyramids the angles of which are more or less prolonged; and they have no actual organic structure. By Nathorst, however, they are regarded, with much probability, as being produced by the infilling of the cavities of dead Jelly-fishes with mud or sand. On this view the central pyramidal body of *Medusites* represents the cast

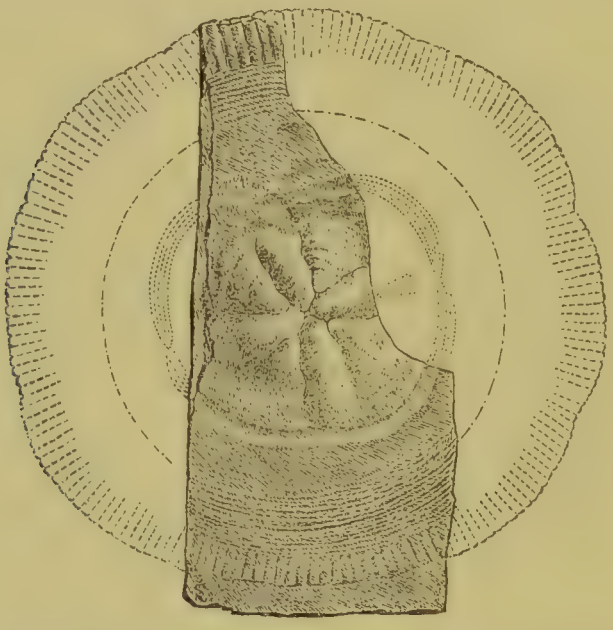


Fig. 90.—The impression of the swimming-bell or a Jelly-fish (*Rhizostomites admirandus*) preserved in the lithographic slate (Jurassic) of Eichstadt, in Bavaria, one-seventh of the natural size. The missing parts are restored in outline. (Copied from Zittel.)

of the gastric cavity of the polypite, while the four or five arms which radiate from this represent casts of the radiating angles of the mouth. In support of this view, Nathorst points to the known habit of certain Jelly-fishes of lying at the bottom with the umbrella turned down and the mouth directed upwards, in the position figured in fig. 89, and he shows how this would naturally facilitate the filling of the gastric cavity with mud. Moreover, Nathorst has shown that bodies exceedingly similar in form and marking to the Cambrian *Medusites* can be produced by taking casts of the internal cavities of fresh specimens of Jelly-fishes in dilute plaster of Paris.

Lastly, Nathorst has brought forward evidence to show that Jelly-fishes are capable of producing various peculiar markings by their

movements when creeping about on the muddy bottom of the sea in shallow water, or by the trailing of their tentacles over soft sediment. In view of this evidence, he has suggested that the peculiar striated and furrowed markings in the Cambrian rocks ("Fucoidal Sandstone") of Sweden which have been described under the name of *Eophyton* (fig. 91), are to be regarded as really produced by the trails of Jelly-fishes. These peculiar markings were originally described as the remains of land-plants, but it seems certain that this

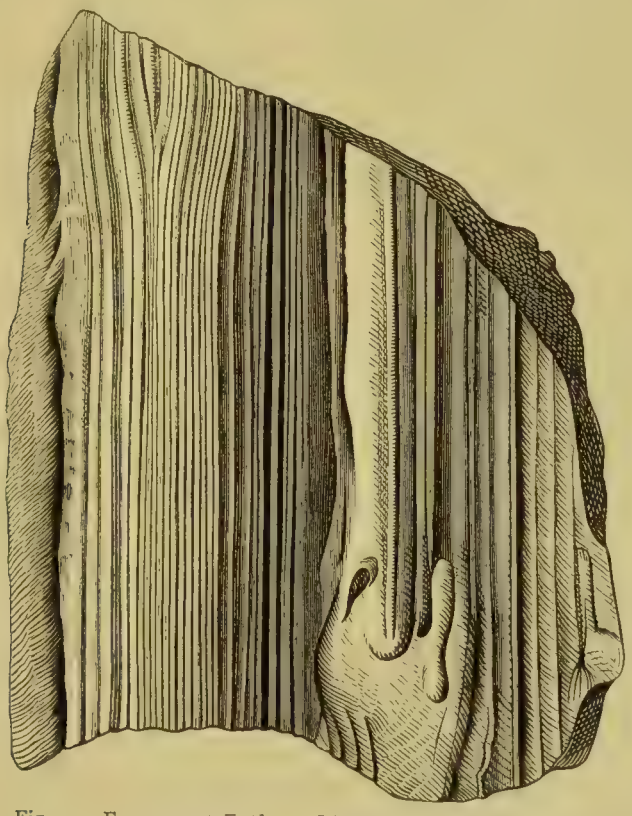


Fig. 91.—Fragment of *Eophyton Linneanum*. Lower Cambrian.

cannot be their real nature. Nathorst has, in fact, produced precisely similar markings by allowing plants to trail over soft mud; and if the so-called *Medusites* of the Swedish Cambrian is rightly regarded as founded on the casts of the gastric cavity of Jelly-fishes, we have in these a proof that there existed at the time animals capable of producing the striated trails of the same deposits to which the name of *Eophyton*[1] was originally applied.

[1] The fossil described by Hicks from the Cambrian rocks of Wales under the name of *Eophyton explanatum* has been shown by Hinde to be really the anchoring-rope of a Hexactinellid Sponge.

CHAPTER XIV.

HYDROZOA — Continued.

Sub-class Graptolitoidea.

The organisms comprised under the head of *Graptolitoidea* (the *Rhabdophora* of Allman) are commonly known as "Graptolites," and constitute a remarkable assemblage of extinct *Hydrozoa*, all the known forms of which are confined to the Upper Cambrian, Ordovician, and Silurian deposits. The Graptolites may be defined (if the abnormal genus *Corynoides* be excluded) as being composite *Hydrozoa* in which the organism consists of numerous polypites united by a cœnosarc; the latter being enclosed in a tubular, chitinous polypary, usually forming a complete external membrane of considerable strength, while the former were protected within "hydrothecæ." The polypary may be undivided or branched, and was invariably free, the organism apparently floating in the water with the proximal end of the colony directed upwards. In most cases, the polypary is strengthened by a peculiar rod-like axis (the "virgula"), which lies in a groove on the dorsal side of the polypary (*i.e.*, on the side opposite to that on which the hydrothecæ are developed), and may be prolonged beyond one or both ends of the colony. The polypary is, typically if not universally, furnished at its proximal end with a minute triangular or dagger-shaped body (the "sicula"), which represents the embryonic skeleton.

As regards its *development*, the earliest condition in which a typical Graptolite presents itself is that of a small triangular corneous body, which has been termed by Professor Lapworth the "sicula" (fig. 92, A), and which is the starting-point of the entire polypary. In its earliest stage (fig. 92, A *a*) the "sicula" is merely a triangular horny sheath lodging the cœnosarc, but a rod-like axis or "virgula" (fig. 92, A *b*) is soon developed along its entire length, often projecting freely at one or both extremities. In the next stage (fig. 92,

A *c*) a bud, constituting the first hydrotheca, appears on one side, near the thicker end of the "sicula." If the form under observation belongs to the group of Graptolites in which the polypary possesses two rows of hydrothecæ (the "diprionidian" Graptolites), a second bud next appears on the opposite side of the "sicula" to the first one, and a little in advance of it. In the further development of the polypary, the sicula appears to remain stationary, usually persisting

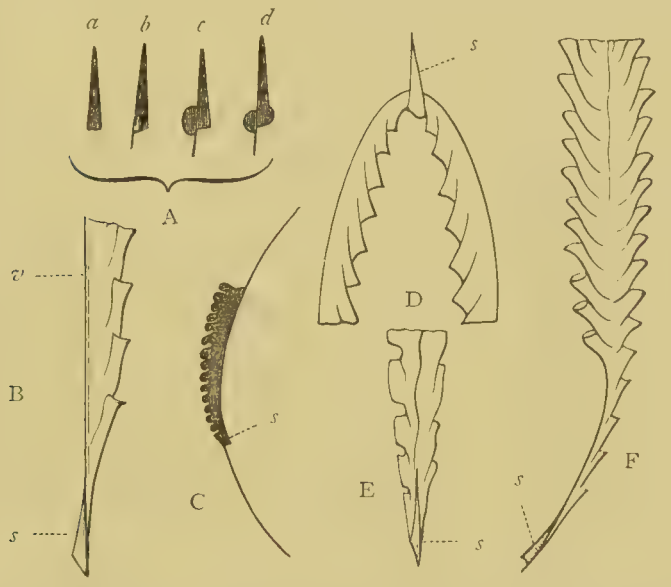


Fig. 92.—A, Early stages in the development of Graptolites: *a*, The earliest stage of the "sicula," in which no virgula is developed; *b*, Later stage, with a virgula; *c*, Still later stage, with a single primordial hydrotheca; *d*, Stage with two hydrothecæ. B, Base of *Monograptus gregarius*, enlarged; C, *Monograptus Clingani*, young specimen, of the natural size, showing a proximal and distal extension of the virgula; D, Proximal portion of *Didymograptus Murchisoni*; E, Proximal portion of *Climacograptus normalis*, enlarged; F, Proximal portion of *Dimorphograptus*, enlarged. *s* Sicula; *v* Virgula. All the specimens are Ordovician or Silurian. (Partly after Lapworth and Tullberg, and partly original.)

at the base of the organism as a dagger-shaped process, the broad end of which is directed proximally (fig. 92, B—F). In some cases the sicula becomes obsolete, or it may ultimately develop into a branch, or, rarely, into a vesicle (as in *Diplograptus physophora*).

Taking a simple Graptolite, such as *Monograptus priodon* (fig. 93), as the type of the sub-class, the polypary will be seen to consist of three principal morphological elements—viz., the cœnosarc, the hydrothecæ, and the virgula. The last mentioned of these—often spoken of as the "axis"—is one of the most characteristic of the structures of the Graptolitic polypary, and has the form of a cylindrical fibre or rod, probably hollow internally, which gives support to the flexible chitinous skeleton. It runs, in such types as *Monograptus*, along the dorsal side of the polypary, opposite to the hydro-

thecæ (fig. 93, B), whereas in the double Graptolites it occupies a central or sub-central position, between the two rows of hydrothecæ which form the biserial colony. In any case it lies in a groove in the periderm, and is really outside the cœnosarc. Very commonly, the virgula projects beyond one or both ends of the polypary as a longer or shorter naked rod (fig. 92, C, and fig. 94, A); the proximal extension being often spoken of as the "radicle," though this name has also been used for the "sicula." Running parallel with the virgula is the cœnosarc — often spoken of as the "common canal"—which is enclosed in the tubular periderm, and presents itself in compressed specimens as a flat space of variable width between the virgula and the bases of the hydrothecæ (fig. 94, *c*). Springing from the cœnosarc, lastly, is a series of chitinous cups or "hydrothecæ," which have often been spoken of as the "cellules" or "denticles." Each hydrotheca rests by its base upon the cœnosarcal canal, is separated from its neighbours by a definite partition, and opens at its apex by an "aperture," through which the contained polypite could protrude its tentaculate head. The hydrothecæ vary extremely in form and in the precise position of the aperture in different types of Graptolites, or in different species of the same genus (fig. 94); and the lip of the aperture may be variously ornamented with spines. Lastly, the hydrothecæ are typically so disposed that they more or less extensively overlap one another (fig. 94, B and C).

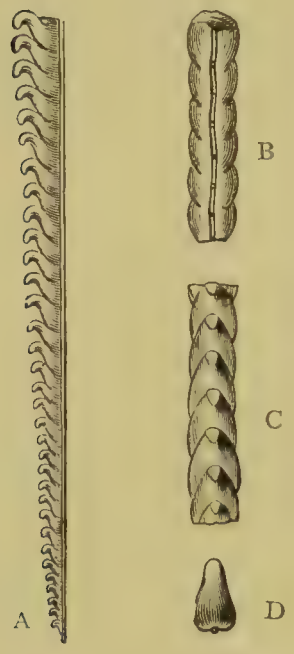


Fig. 93. — Morphology of *Monograptus priodon*. A, *Monograptus priodon*, Bronn, preserved in relief—lateral view slightly enlarged—from the Silurian rocks; B, Dorsal view of a fragment of the same species — considerably enlarged; C, Front view of a fragment of the same, showing the mouths of the hydrothecæ — much enlarged; D, Transverse section of the same. (Original.)

While the above is the arrangement of parts in such a form as *Monograptus priodon*, there are many departures from this typical condition in other forms of the Graptolites. Thus, the general periderm, instead of forming a dense continuous membrane, may, as in *Retiolites* (fig. 106), be reduced to a mere network of chitinous threads. In the same genus, the virgula is double, the two halves being placed on opposite sides of the cœnosarc, and being united with the peridermal network. Again, the hydrothecæ, instead of more or less largely overlapping one another, may, as in *Rastrites* (fig. 98), spring quite separately and at greater or smaller intervals from the cœnosarc. Lastly, it has not been certainly estab-

lished that the "virgula" is invariably developed in all types of the Graptolites, and the name of *Rhabdophora*, proposed for the group by Professor Allman, is, therefore, not wholly appropriate.

With regard to the *reproductive process* in the Graptolites there are strong grounds for supposing that the generative elements were developed in specially modified polypites, or "gonophores," after a manner analogous to that which occurs in the Hydroid Zoophytes generally. In some cases, these generative buds may have been destitute of a hard covering, and therefore incapable of preservation;

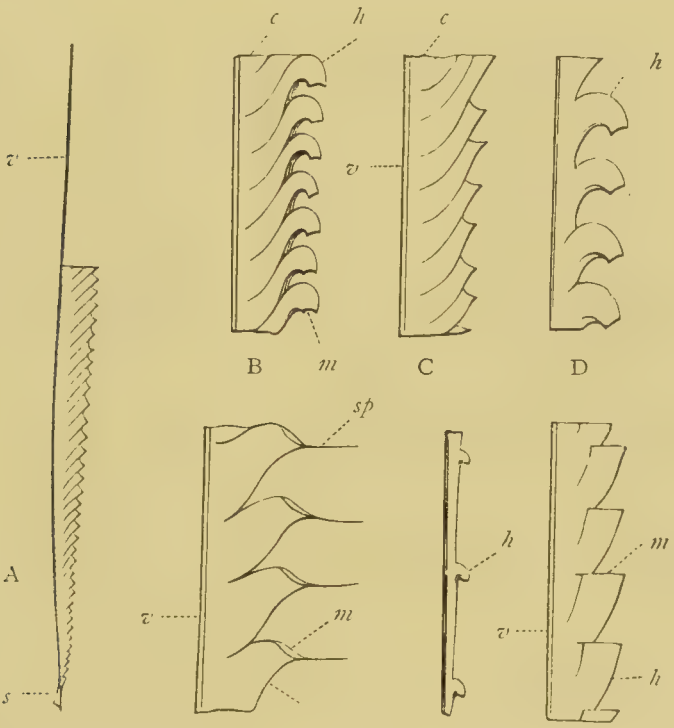


Fig. 94.—A, *Monograptus colonus*, enlarged; B, A fragment of *Monograptus priodon*; C, *Monograptus colonus*; D, *Monograptus Clingani*; E, *Monograptus spinigerus*; F, *Monograptus attenuatus*; G, *Monograptus Hisingeri*, all greatly enlarged. *s*, Sicula; *v*, Virgula; *c*, Cœnosarc; *h*, Hydrotheca; *m*, Aperture of hydrotheca; *sp*, Apertural spine. (After Lapworth.)

but in other cases there is evidence of the existence of chitinous receptacles, of larger size than the hydrothecæ, and of different form, which may be compared with the "gonangia" or "ovarian capsules" of the recent Sertularians, and may be supposed to have lodged the reproductive zoöids. Thus, occasional specimens of certain of the diprionidian Graptolites have been found to carry on their sides singular horny sac-like structures, which can hardly be regarded as anything else than as of the nature of "gonangia." Moreover, it is

very usual, as pointed out by the writer, to find in association with Graptolites peculiar, bell-shaped or conical, chitinous capsules, which may be spoken of by the general name of *Dawsoniæ* (fig. 95). These capsules present different appearances in accordance with the direction in which they have been compressed, and they vary in shape and size. Each is furnished with a little spine or mucro at its summit, and also with a marginal chitinous thread or fibre. These singular bodies have not hitherto been certainly detected in direct connection with the polypary of any Graptolite. They may, however,

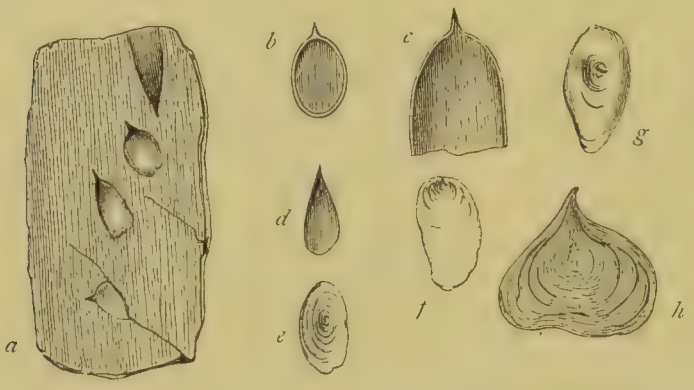


Fig. 95.—Various forms of bell-shaped chitinous capsules (*Dawsonia*) found associated with Graptolites, and supposed to be of the nature of "gonangia." (Original.)

be regarded, with great probability, as being of the nature of "gonangia," though they probably differed from the structures so called in the recent Sertularians in becoming detached from the parent colony.

Two leading *types of structure* may be distinguished amongst the Graptolites, and these may be respectively termed the "monoprionidian" and "diprionidian" type. The monoprionidian Graptolites (*Monoprionidæ*) are distinguished by the fact that, whether the colony be simple or branched, the hydrothecæ are arranged in a single series, and the cœnosarc is thus single and not double. In the typical *Monoprionidæ* the hydrothecæ are uniserial over the entire polypary (as in *Monograptus* or *Didymograptus*). A transition is, however, effected between the monoprionidian and diprionidian groups of Graptolites by such intermediate types as *Dimorphograptus* (fig. 92, F) in which the proximal portion is monoprionidian and the distal portion diprionidian, or *Dicranograptus* (fig. 103, A) in which the opposite state of things obtains. On the other hand, in the proper *Diprionidæ* the polypary is duplicate, and consists of two separate rows of hydrothecæ, which may spring from an undivided common cœnosarc, but which, more usually, arise from

two separate cœnosarcal tubes which are closely apposed to one another, back to back, along their entire length.

Before briefly considering some of the leading types of these two great groups, attention may be directed for a moment to the singular genus *Corynoides* (fig. 96), which differs in important respects from all the ordinary Graptolites. In this curious form the organism consists of a cylindrical chitinous tube, tapering towards the base, where it is furnished with two small spines, and expanding above into a species of toothed cup. The polypary does not show any signs of having been attached to any foreign body, and the suggestion has been thrown out by Lapworth, that the type may be regarded as a Graptolite which never proceeded beyond the stage of a "sicula."

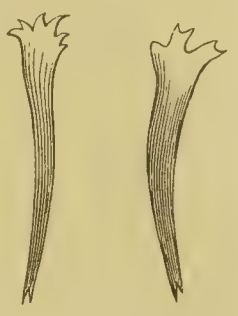


Fig. 96.—*Corynoides calicularis*, enlarged. (Original.)

The type of the Monoprionidian Graptolites is the genus *Monograptus* itself (figs. 93 and 94), which is also the central genus of the family of the *Monograptidæ*. In this genus the polypary is simple and linear, possessing but a single row of hydrothecæ on one side, and commencing by an attenuated, often curved base. The polypary is straight, curved, or helicoid in different forms; and great variations exist in the shape of the hydrothecæ in different species (fig. 94), these structures usually, but not always, overlapping to a greater or less extent. The "sicula" is attached along the dorsal margin of the proximal end of the polypary (fig. 92, B). All the species of *Monograptus* are confined to the Silurian rocks proper (the Upper Silurian of Murchison), ranging from the base to the summit of the system. In the allied genus *Cyrtograptus* (fig. 97) the polypary is also unilateral, in so far as the hydrothecæ are produced from the sicula in one direction only, but the polypary is now branched. This genus is also confined to the Silurian rocks proper. Again, in the genus *Rastrites* (fig. 98) the polypary resembles that of *Monograptus* in form, but the hydrothecæ are more or less linear,

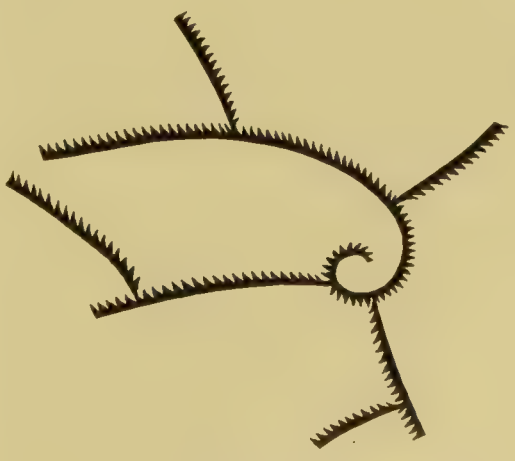


Fig. 97.—*Cyrtograptus Murchisoni*, Carr. (After Carruthers.)

and are isolated from one another, instead of overlapping. The species of this genus are, like those of the preceding genera, restricted to the Silurian rocks proper.

The family *Leptograptidæ* has been founded by Lapworth for a number of bilaterally-symmetrical branched Graptolites, which agree with one another in having the hydrothecæ attached along

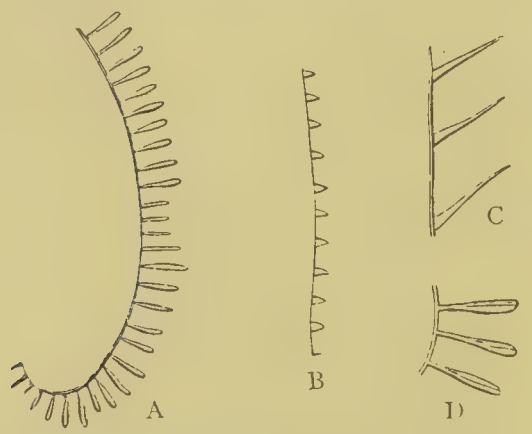


Fig. 98.—A, *Rastrites peregrinus*; B, *Rastrites capillaris*; C, *Rastrites Linnæi*; D, Fragment of *Rastrites peregrinus*, greatly enlarged. All the figures are magnified. Silurian. (Original.)

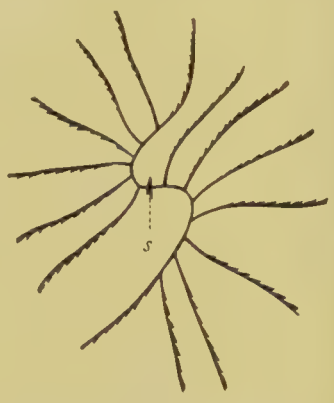


Fig. 99.—*Cœnograptus gracilis*, of the natural size. *s* Sicula. Ordovician. (After Lapworth.)

the whole of one face to the cœnosarc, and not overlapping. The form of the polypary varies much in this family, consisting of two long primary branches in *Leptograptus* itself, but being rendered complex in *Pleurograptus* by the development of secondary branches from each of the long primary stems, these in turn sometimes giving off tertiary branches. In the beautiful genus *Cœnograptus* (fig. 99), again, the two primary stems originate from the centre of a triangular sicula, and form an S-shaped frond, the convex sides of which give off simple branches. All the above genera are found in the Ordovician rocks, but do not extend upwards into the Silurian proper.

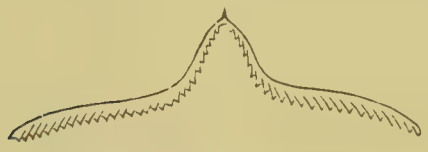


Fig. 100.—*Didymograptus* V-*fractus*. Ordovician (Skiddaw Slates).

The great family of the *Dichograptidæ* comprises a large number of branched Graptolites, all the forms of which are found in the Upper Cambrian and Ordovician deposits. The simplest type of this family is the genus *Didymograptus* (figs. 92, D, and 100), in which the polypary consists of two simple branches springing from a small pointed "sicula." The angle included between the polypiferous sides of the two branches ("angle of divergence") is always less than 180°, the opposite

angle ("sicular angle") being necessarily over 180°. The species of *Didymograptus* are confined to the Ordovician rocks. Closely allied to the preceding is the genus *Tetragraptus* (fig. 101) in which the polypary consists of four simple branches springing from a central, non-polypiferous connecting-process or "funicle," which bifurcates at each end. The base is sometimes provided with a peculiar corneous disc, similar to that which characterises various species of *Dichograptus*. The species of *Tetragraptus* are all Ordovician (Arenig). In the genus *Dichograptus* (fig. 102), again, the polypary consists of eight simple branches, which arise from the same number of divisions of a non-polypiferous basal process or "funicle." In many cases, the divisions of the "funicle" are enveloped in a species of horny "disc" or plate (fig. 102), which is believed to have been composed of two laminæ. The functions of this disc are doubtful, but it has been compared with the "float" of the Portuguese-Man-of-war (*Physalia*) or of *Velella* among the recent Oceanic *Hydrozoa*. The species of *Dichograptus* are confined to the lower portion of the Ordovician series (Arenig); but allied genera, in which the polypary is irregularly branched, are found in the Upper Cambrian deposits, and are represented in the Ordovician rocks.

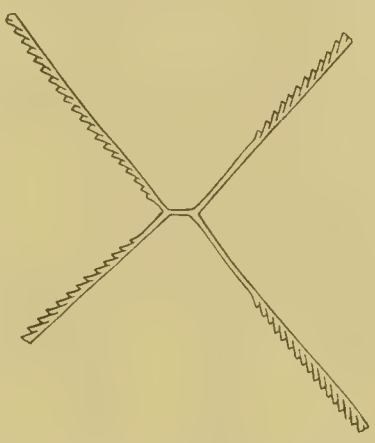


Fig. 101.—*Tetragraptus quadribrachiatus* (after Hall). Ordovician (Skiddaw and Quebec groups).

The only remaining family of the Monoprionidian Graptolites is that of the *Dicranograptidæ*, comprising the two genera *Dicranograptus* and *Dicellograptus*, in both of which the polypary is composed of two branches, and the terminations of the hydrothecæ are isolated and characteristically incurved, so as to bring the cell-apertures within the line of margin of the branch (fig. 103). In the genus *Dicellograptus* (fig. 103, B) the two branches of the polypary are wholly free, and diverge from a basal "sicula," in such a manner as to resemble the genus *Didymograptus*. The angle included between the polypiferous sides of the branches ("angle of divergence") is, however, greater than 180°, while the opposite angle ("sicular angle") is necessarily less than 180°. In the curious genus *Dicranograptus* (fig. 103, A) we have a transition between the Monoprionidian and Diprionidian groups of Graptolites, the two branches composing the polypary being adherent by their dorsal surfaces for a longer or shorter distance, and then diverging

freely. The species of both these genera are confined to the Ordovician rocks.

Coming next to the group of the Diprionidian Graptolites, the typical family is that of the *Diplograptidæ*, of which the type-genus is *Diplograptus* itself. In this genus the polypary (fig. 104) consists—as it does in most of the genera of the family—of two simple monoprionidian branches, which are closely united to one another along their flattened dorsal surfaces, but are enclosed in independent peridermal sheaths, and are therefore really separate. The virgulæ of the two branches coalesce, and form a single rod-like axis, which is embedded in a groove between the cœnosarcal sheaths, and commonly projects distally as a naked fibre, while it appears proximally as a shorter or longer "radicle" (figs. 104 and 105). In some of the *Diplograptidæ*, however, according to Lapworth, there is only a single cœnosarcal canal from which the two rows of hydrothecæ

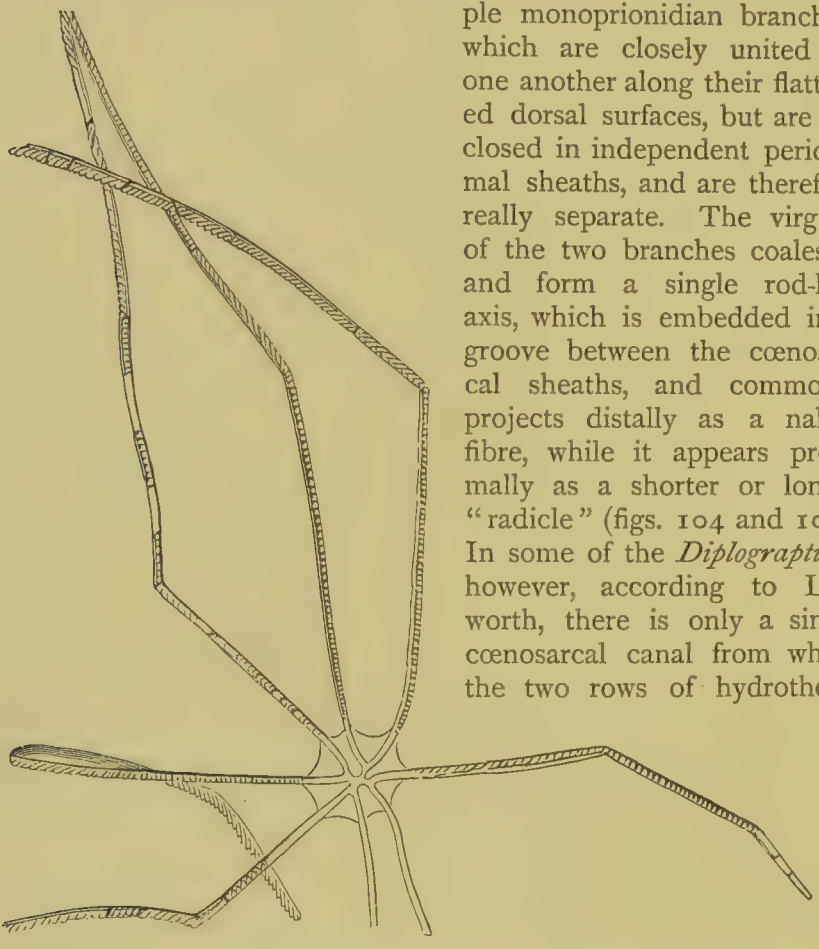


Fig. 102.—*Dichograptus octobrachiatus*, showing the central disc. (After Hall.) Ordovician (Skiddaw and Quebec groups).

spring. The hydrothecæ themselves overlap each other to a greater or less extent, the distal portion of each being free. The species of *Diplograptus* are found in both the Ordovician and Silurian rocks. In the nearly allied genus *Climacograptus* (fig. 105), the structure is much the same as in *Diplograptus*, but the hydrothecæ are vertically disposed, in such a manner that their mouths appear to be sunk below the general surface of the polypary. The appearances presented by the polypary in this genus vary extremely, according to

the manner in which the organism has been compressed, or the particular view of the cell-apertures which may be afforded by a given specimen (fig. 105, C, D, E). The species of the genus are all Ordovician and Silurian. Of the remaining genera of the *Diplograptidæ* the only one which needs special notice is the remarkable *Dimorphograptus* (fig. 92, F), in which the proximal portion of the polypary is monoprionidian, while the distal portion is diprionidian. The polypary in its basal part thus resembles a *Monograptus*, which genus it also approaches in the possession of

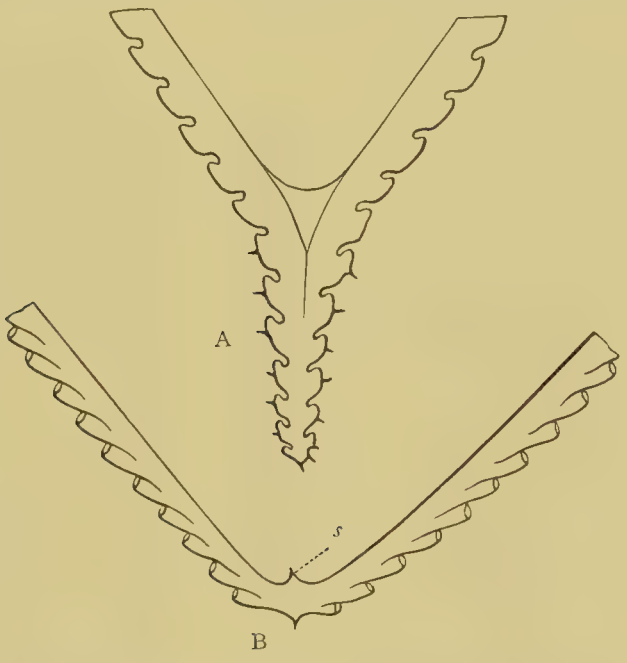


Fig. 103.—A, Proximal portion of the polypary of *Dicranograptus Nicholsoni*, enlarged five times; B, Proximal portion of the polypary of *Dicellograptus complanatus*, enlarged. Ordovician. (After Hopkinson and Lapworth.)

an adherent "sicula"; while in its upper portion it has the characters of an ordinary *Diplograptus*. The known species of *Dimorphograptus* are all Silurian.

Of the remaining families of the Diprionidian Graptolites, the *Lasiograptidæ* are not thoroughly understood, but their distinguishing feature is found in the fact that the biserial polypary is provided with peculiar chitinous spines, arising from the hydrothecæ, which subdivide and inosculate with one another so as to surround the colony with a kind of netted fringe of fine fibres. The type-genus, *Lasiograptus*, is Ordovician. The family of the *Retiolitidæ* is also a peculiar one, the characteristic feature being that the periderm is very much attenuated, and is supported upon a remarkable network

of chitinous fibres, thus producing a minutely latticed appearance of the surface (fig. 106). According to Lapworth, the two virgulæ of the biserial polypary are separated, and are attached to opposite sides of the peridermal network. The type-genus is *Retiolites* itself, the species of which are Ordovician and Silurian. Lastly, the family of the *Phyllograptidæ* includes the single genus *Phyllograptus*, all the species of which are confined to the lower portion of the Ordovician system. In this genus (fig. 107) the polypary is leaf-

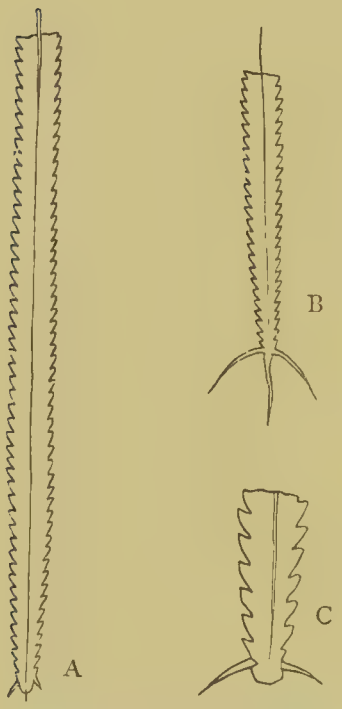


Fig. 104.—A, *Diplograptus foliaceus*, slightly enlarged; B, A *Diplograptus* showing two long lateral spines, in addition to a central "radicle"; C, Base of a *Diplograptus*, enlarged. Ordovician. (Original.)

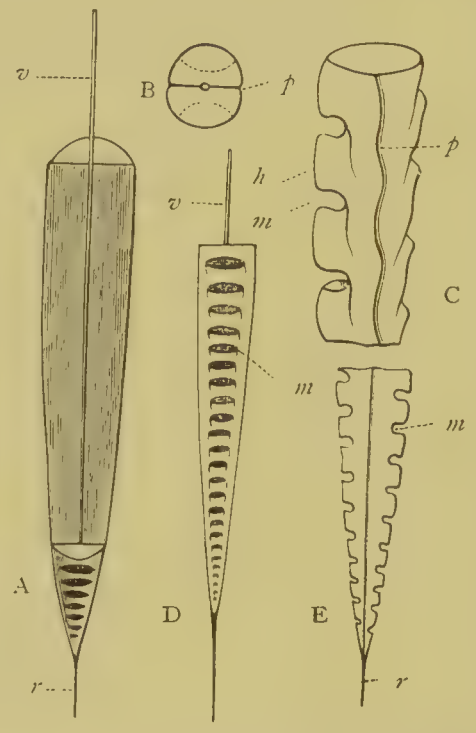


Fig. 105.—A, A specimen of *Climacograptus normalis*, in relief and partially split in half, showing the virgula embedded between the two branches of the duplex polypary; B, Transverse section of the polypary of the same; C, D, and E, Different views of the polypary of the same, showing the appearances produced by differences in the direction of compression. *r*, Radicle; *v*, Virgula; *p*, Septum between the two halves of the polypary; *h*, Hydrotheca; *m*, Aperture. All the figures are enlarged. Silurian. (Original.)

like, and consists of *four* rows of hydrothecæ placed back to back, in such a manner as to resemble two *Diplograpti* intersecting one another at right angles. In consequence of this peculiar structure of the polypary, the *Phyllograpti* are sometimes spoken of as the "tetraprionidian" Graptolites.

The Graptolites have been considered with some detail on account of their great importance in determining the chronological succession

of the Ordovician and Silurian deposits, as has been amply demonstrated by the researches of Lapworth, Linnarsson, and others. Regarded as a whole, the Graptolites, as previously stated, are restricted to the Upper Cambrian, Ordovician, and Silurian rocks, but particular types have been shown to be characteristic of particular horizons in these rock-systems. This is not the place to give an account of the general succession of the *Graptolitoidea* in time, or to indicate the precise stratigraphical value of particular forms of the group, but some general results may be briefly alluded to. The great family of the *Monograptidæ* is wholly confined to the Silurian rocks proper (Upper Silurian of Murchison), the genus *Monograptus*

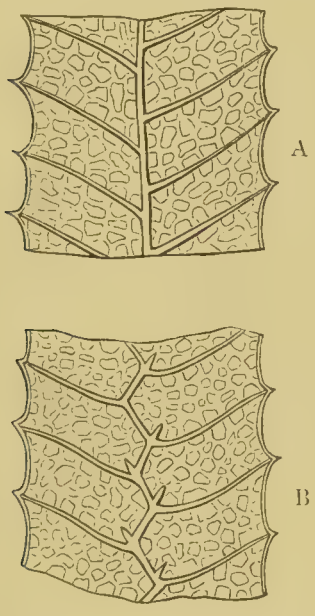


Fig. 106.—Different views of portions of *Retiolites venosus*, enlarged nine times, showing the netted periderm and the virgula. (After Hall.)



Fig. 107.—Group of individuals of *Phyllograptus typus*, from the Quebec group of Canada (after Hall). One of the four rows of cells is hidden on the under surface.

itself extending from the base of this system to its summit. On the other hand, the families of the *Diplograptidæ* and *Retiolitidæ* range from the base of the Ordovician rocks to the middle of the Silurian. The families of the *Leptograptidæ*, *Dicranograptidæ*, *Lasiograptidæ*, and *Phyllograptidæ* are restricted to the Ordovician rocks, and the species of *Phyllograptus*, the sole representative of the last of these families, is only found in the basal beds (Arenig and Llanvirn beds) of the Ordovician. Lastly, the great family of the *Dichograptidæ* commences in the Upper Cambrian period, culminates in the lower Ordovician, and dies out altogether before the commencement of the Silurian. The horizon of the Arenig rocks (Skiddaw and Quebec

groups) is especially characterised by the presence of such genera as *Dichograptus* and *Tetragraptus*, species of these genera being found in rocks of this age in localities as remote as Canada, Britain, and Australia.

Finally, as regards the *zoological affinities* of the Graptolites, palæontologists are now agreed in regarding these singular organisms as an ancient and aberrant type of the *Hydrozoa*. In many respects the Graptolites present a resemblance to the recent Sertularians, this resemblance being shown not only in the fact that the hydrothecæ have a general likeness in form and arrangement in the two groups, but also in the possession by certain of the former of chitinous reproductive capsules, which admit of comparison with the "gonangia" of the latter. On the other hand, the polypary of the Sertularians is always fixed, the hydrothecæ are never in contact, and the colony is not specially strengthened by a horny fibre. In contradistinction, the Graptolites were free organisms, originating in a basal "sicula," the hydrothecæ are usually (but not always) more or less largely in contact, and the polypary is strengthened by the peculiar chitinous rod which has been previously spoken of as the "virgula." In the singular recent genus *Rhabdopleura*, one of the marine *Polyzoa*, the polyzoary is strengthened by a peculiar hollow chitinous axial tube, which has been compared by Professor Allman with the "virgula" of the Graptolites. There are, also, points of resemblance between the Graptolites and those *Polyzoa* (such as *Vesicularia*) in which the cells of the colony communicate by means of a common tube. None of the *Polyzoa*, which possess a chitinous external skeleton, are, however, free and unattached, and the general balance of evidence is unquestionably in favour of a reference of the *Graptolitoidea* to the class of the *Hydrozoa*.

CHAPTER XV.

HYDROZOA — Continued.

HYDROCORALLINES AND STROMATOPOROIDS.

Sub-class Hydrocorallinæ.

The name of *Hydrocorallinæ* has been proposed by Professor Moseley for two groups of marine *Hydrozoa* which produce a regular skeleton of carbonate of lime, and which, on the strength of the skeleton alone, were formerly referred to the true Corals (*Actinozoa*). The two groups in question are the *Milleporidæ* and *Stylasteridæ*, the former being represented by the well-known *Millepora*, which contributes largely to the formation of coral-reefs in various regions. The "cœnosteum" or calcareous skeleton of *Millepora* (fig. 108) is usually in the form of a foliaceous or laminar expansion, or is simply branched, and though minutely spongy, is of considerable density. The main mass of the skeleton is essentially composed of a complex network of anastomosing calcareous fibres, so disposed as to give rise to a correspondingly complex network of anastomosing and tortuous canals (fig. 109, *c c*). In the living condition, this canal-system is filled with anastomosing stolons of the cœnosarc, by which the different zoöids of the colony are placed in organic connection. The general spongy skeleton, constituted as above described, is traversed at intervals by the vertical tubes in which the zoöids were contained. These tubes are in two series, differing slightly in size, and they open on the surface by apertures correspondingly different in dimensions, of which the larger ones are called the "gastropores" and the smaller the "dactylopores" (fig. 108, *g* and *d*). The gastropores and dactylopores may be irregularly distributed, or the dactylopores may be arranged in more or less definite systems round the gastropores. These two sets of tubes, as shown by Moseley, lodge respectively larger and smaller zoöids, which differ in structure and function.

The large zoöids ("gastrozoöids") possess a mouth and digestive cavity, and have from four to six short tentacles. On the other hand, the smaller zoöids ("dactylozoöids") have no mouth, and possess short clavate tentacles on their sides: they are long and slender, and perform the function of prehension for the colony. Whatever may be the structure of the contained zoöids, the zoöidal tubes are intersected internally by distinct transverse calcareous partitions or "tabulæ" (fig. 108, C, and fig. 109, B); but there are no traces of radiating vertical partitions or "septa." The entire cœnosteum shows a more or less evident composition out of thin

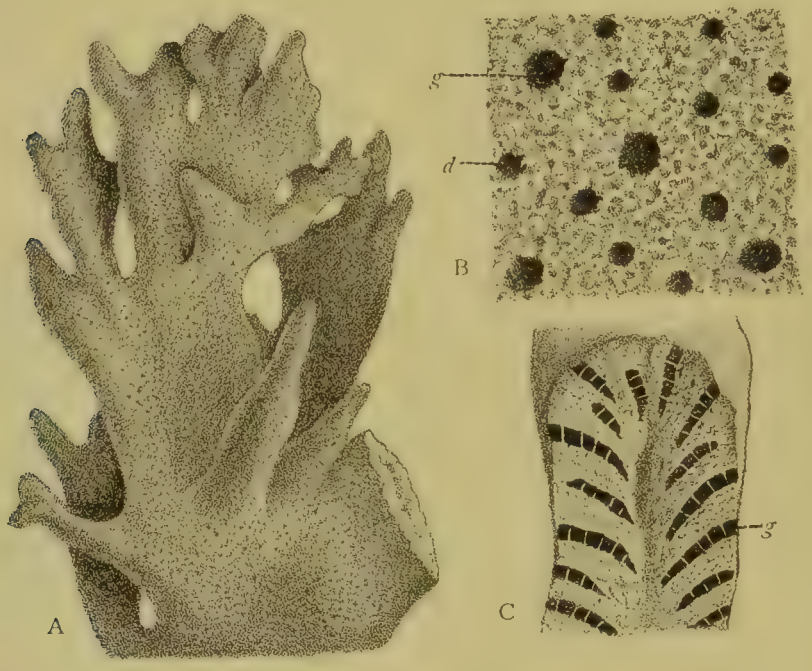


Fig. 108.—A, Portion of the cœnosteum of *Millepora alcicornis*, of the natural size; B, Part of the surface of the same enlarged, showing the mouths of the "gastropores" (*g*) and "dactylopores" (*d*), and the intermediate cœnosteal tissue; C, Vertical section enlarged, showing the tabulate zoöidal tubes. (Original.)

concentric laminæ, only a thin surface-layer being at any given moment actually alive. The reproductive process in *Millepora* is imperfectly known, but Mr Quelch has shown that in one species of the genus the reproductive zoöids are developed within special globular cavities or "ampullæ," which are contained within the general spongy skeleton, and are covered by a thin porous layer.

The structure of *Millepora* has been dwelt upon at some length, as throwing considerable light upon the relationships of the extinct Stromatoporoids, but the genus itself is of little palæontological importance. The earliest known forms of the genus appear in the

Eocene rocks; and in the same formation appears the allied genus *Axopora*, which differs from *Millepora* chiefly in the fact that the tabulate zoöidal tubes are traversed by a large fasciculate "columella" or central rod. The Cretaceous genus *Porosphæra* has been regarded as related to *Millepora*, but it appears to be truly referable to the Sponges.

The second group of the Hydrocorallines is that of the *Stylasteridæ*, comprising a number of recent genera (*Stylaster*, *Allopora*, *Cryptohelia*, *Sporadopora*, &c.), all of which are inhabitants of the sea, and range from the neighbourhood of the coast-line to great depths. The cœnosteum of the Stylasterids is calcareous, more or

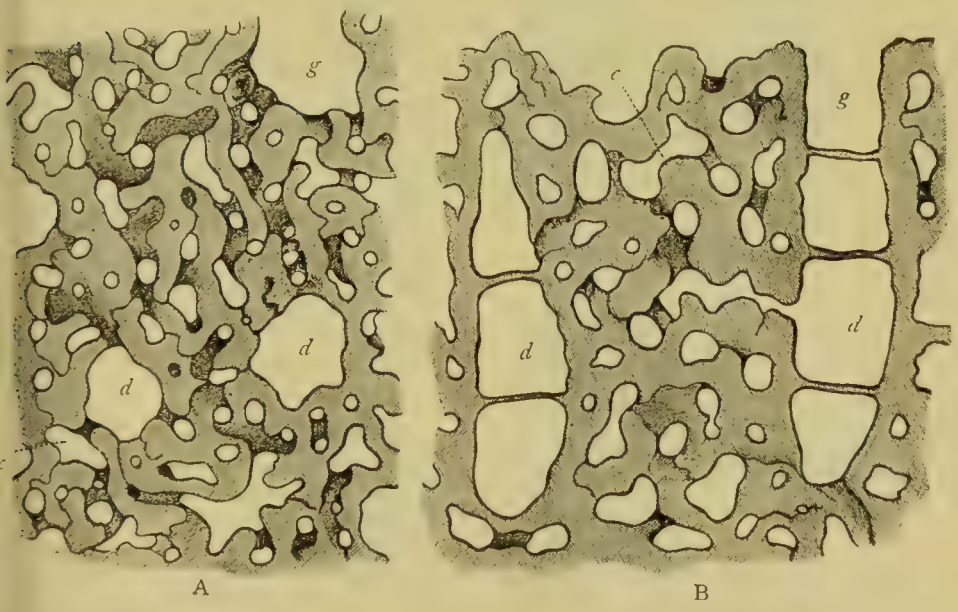


Fig. 109.—Thin sections of *Millepora*, sp., enlarged about thirty-five times. A, Tangential section. B, Vertical section. *g g*, Gastropores; *d d*, Dactylopores; *c c*, Cœnosarcal canals. (Original.)

less branched, forming a dendroid colony or flabellate expansion, and exhibiting upon the surface, or on its sides, small rounded apertures which usually have the appearance of being intersected marginally by radiating partitions or septa, and thus simulate the "calices" of an ordinary Madreporarian Coral (fig. 110). In other cases, the surface shows a series of large apertures, with more numerous and irregularly arranged smaller openings, the latter not being radially arranged round the former. Thin sections of the cœnosteum (fig. 111) show that the general skeleton is composed of a dense, subcrystalline calcareous tissue, which is traversed in all directions by a system of branched and anastomosing canals, which in the living

condition are occupied by prolongations of the cœnosarc, and which place the different zoöids of the colony in direct connection. The zoöids are of two kinds, differing in size, structure, and function. The larger zoöids ("gastrozoöids") are provided with a mouth and stomach-sac; while the others ("dactylozoöids") are elongated and destitute of a mouth, thus coming to represent tentacles in form. The gastrozoöids occupy, as in *Millepora*, the large tubes of the skeleton, and the dactylozoöids are lodged in the small tubes. Hence, when the dactylozoöids are arranged in definite "cyclo-systems" round the gastrozoöids, then each of the large apertures in the skeleton comes to be surrounded by a circle of smaller elongated pores, which are only separated laterally by thin partitions, and which

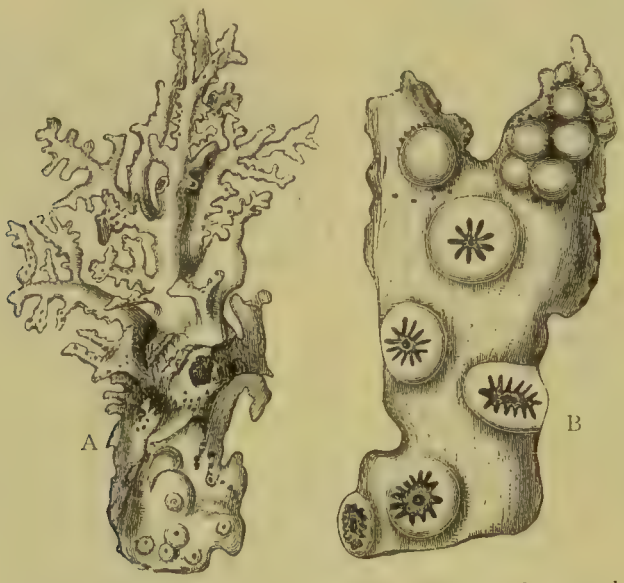


Fig. 110.—A, Portion of the skeleton of *Stylaster sanguineus*, of the natural size; B, Small portion of a branch of the same, enlarged, showing the calices and ampullæ. Living, in the Australian seas. (After Milne-Edwards and Haime.)

thus give rise to the appearance of a central "calice" surrounded by radiated "septa" (fig. 111, c). In certain forms of the Stylasterids, as in *Allopora*, the tubes lodging the gastrozoöids are occupied inferiorly by a reticulate calcareous style or "columella" (a similar structure occasionally existing in the dactylopores); and transverse calcareous partitions or "tabulæ" are sometimes present, though usually in small numbers. Lastly, reproduction in the Stylasterids is effected by means of reproductive zoöids developed within special sac-like cavities or "ampullæ," which at certain periods communicate with the exterior by means of minute pores.

As regards their *distribution in time*, a few species of Stylasterids have been recognised in the Tertiary deposits, the recent genera

Distichopora and *Allopora* being both represented by Tertiary forms. There are also certain Cretaceous fossils, at present imperfectly known, which, according to Moseley, are probably referable to this group. The most ancient allies of the Stylasterids, however, would appear, from the researches of the present writer, to be the singular Triassic fossils for which Professor P. M. Duncan founded the genera

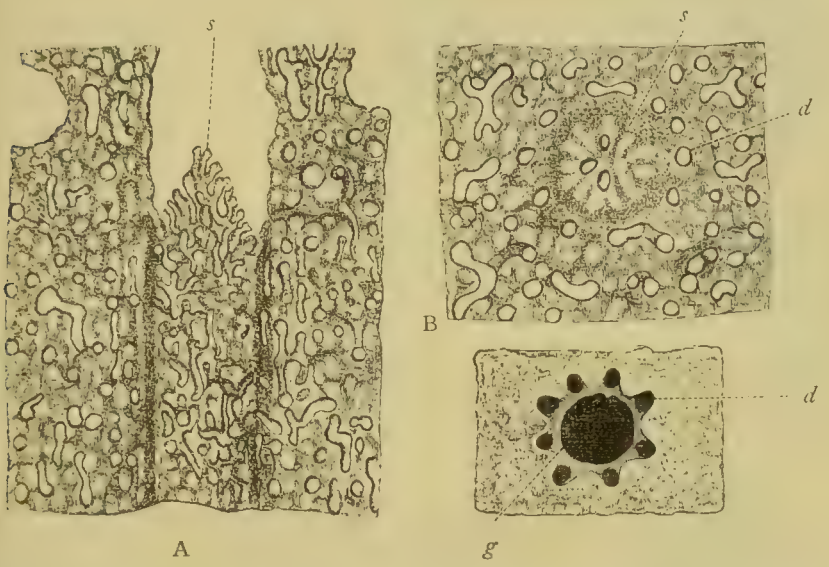


Fig. 111.—A, Vertical section of the cœnosteum of *Allopora*, sp., showing the reticulate cœnosarcal tissue and its canals, greatly enlarged. The section traverses a gastropore, which is seen to be occupied below by a reticulate "columella" (*s*). B, Horizontal section of the same, greatly enlarged, intersecting one of the systems of zoöidal tubes: *s*, Columella of the gastropore cut across; *d*, One of the dactylopores cut across. C, Portion of the surface, enlarged, showing a gastropore (*g*) surrounded by its circle of dactylopores (*d*). (Original.)

Syringosphæra and *Stoliczkaria*.[1] The fossils included in these genera are known as "Karakoram stones," and are found in strata of supposed Triassic age in the Karakoram Mountains, in Kashmir. They are spheroidal or spherical bodies (fig. 112) which vary from an inch or less up to two inches or more in diameter, and which, in unworn specimens, exhibit a warty, verrucose, or granular surface. The surface also generally exhibits rounded pits or pores, which may be uniformly distributed, or which are specially developed along the equatorial diameter of the fossil. There are no traces of any mark of attachment, and the organism must have been free. The

[1] In 1865 Professor Reuss published descriptions and figures of some fossils from the Alpine Trias, for which he proposed the generic name of *Heterastridium* (Sitzungsberichte der Wien Akad. Bd. 51, p. 385, Pls. I.-IV., 1865). It is clear from these that *Heterastridium* is very closely allied to *Stoliczkaria*, if not absolutely identical with it. In case of the identity of these two genera being established, the name of *Stoliczkaria* will have to be abandoned in favour of that of *Heterastridium*, the latter having been published first.

skeleton is calcareous, and its general substance is composed of a characteristic, cancellated or tubulated cœnosarcal tissue, closely resembling the cœnosarcal tissue of *Parkeria*. The tubuli of the general cœnosteal tissue have a radial direction from the centre to the circumference, as in *Parkeria*, but there is no marked arrangement into concentric layers. As seen in cross-sections (fig. 113, A) this tubulated tissue exhibits a characteristic netted appearance. The general cancellated tissue of the skeleton is traversed by numerous comparatively large radiating tubes (fig. 113, *t*), which open on the surface by the rounded apertures above spoken of, and which may be regarded as zoöidal tubes. These tubes, in some cases at any rate, are of differ-

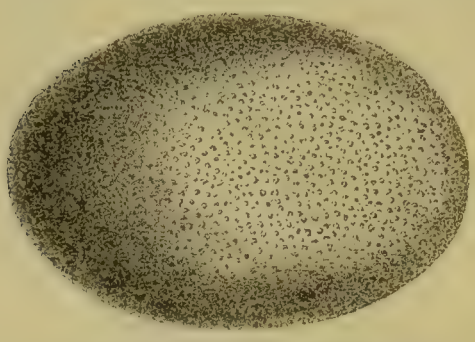


Fig. 112.—A specimen of *Stoliczkaria granulata*, of the natural size, from the Triassic rocks of Kashmir. The surface of the specimen is much worn, but shows the apertures of the zoöidal tubes. (Original.)

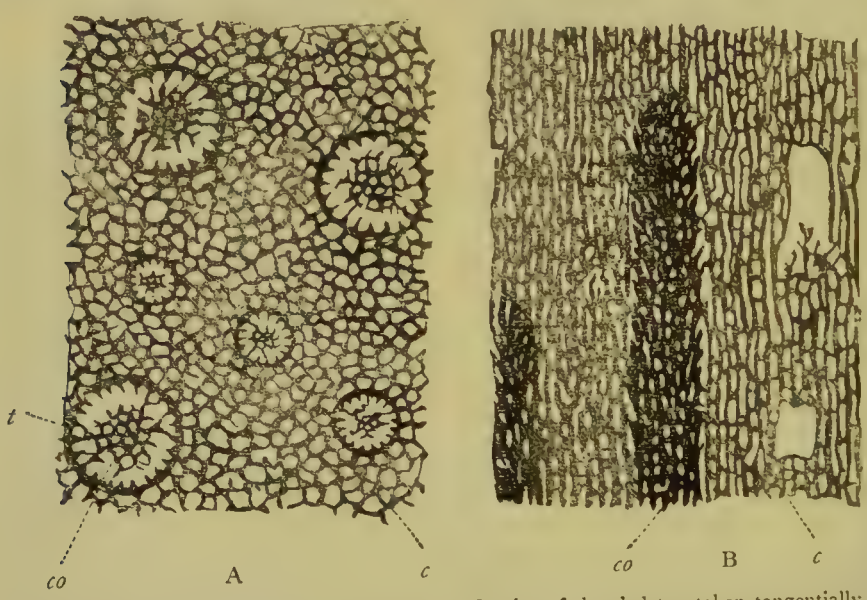


Fig. 113.—Minute structure of *Stoliczkaria*. A, Section of the skeleton taken tangentially to the surface, enlarged twenty-five times, showing the general cancellated cœnosarcal tissue (*c*) and the transversely-divided zoöidal tubes (*t*) with their reticulate columellæ (*co*); B, Vertical section, similarly enlarged, the letters as before. (Original.)

ent sizes, and correspond with the "gastropores" and "dactylopores" of the Stylasterids, and each is provided with a reticulate central style or "columella" (fig. 113, *co*). In cross-sections the

tubes often show the appearance of short inward projections, which have the aspect of the radiating "septa" of a coral, but which are doubtless of a wholly different nature.

The general structure of the skeleton in *Stoliczkaria*, and apparently in *Syringosphæra* also, is thus in many respects similar to that of the recent genera *Allopora* (fig. 111) and *Sporadopora* among the Stylasterids. These singular organisms may therefore be regarded as being referable to the Hydrocorallines, and as being related to the *Stylasteridæ*. From these, however, they differ in their free habit, and in the peculiar radial tubulation of the cœnosarcal tissue; and they may thus be properly considered as constituting a special family, to which the name of *Syringosphæridæ*, proposed by Professor Duncan, may be given. The resemblance between *Stoliczkaria* and *Syringosphæra* on the one hand and *Parkeria* on the other hand, though superficially close, is not dependent on real identity of structure. They agree in the general nature of the cœnosarcal tissue; but the skeleton in *Parkeria* is composed of concentric layers, separated by tiers of chamberlets or by "interlaminar spaces," and is traversed by numerous radial pillars, while the zoöidal tubes are irregular and are devoid of a columellar style.

Sub-class Stromatoporoidea.

The Stromatoporoids constitute a large group of extinct *Hydrozoa*, which, so far as certainly known, are confined to the Ordovician, Silurian, and Devonian rocks. The cœnosteum in the forms included in this group is calcareous and often of large size; and some of the limestones of the Silurian and Devonian period are very largely made up of the skeletons of these organisms. The form of the skeleton and the mode of growth are extremely variable, but the most typical condition of the cœnosteum is that of a spheroidal or irregular mass, or of a flattened expansion, attached basally to some foreign body, and exhibiting a more or less conspicuous composition out of concentric calcareous laminæ (fig. 114). In some cases the skeleton is branched and dendroid, and in others it forms a thin crust growing upon foreign bodies. In this latter case, as well as in some massive types, the organism is attached by the whole of its under surface; but more usually the attachment is by a peduncle, and the greater portion of the basal surface is covered by a thin, concentrically wrinkled, calcareous membrane or "epitheca."

As regards the general structure of the skeleton of the Stromatoporoids, the most obvious feature is that it is composed of numerous concentric layers or "laminæ," which are separated by narrow intervals or "interlaminar spaces." In reality, however, the actually fundamental element in the skeleton is not found in these con-

spicuous concentric laminæ but in a series of vertical calcareous rods ("radial pillars"), which are directed at right angles to the laminæ. The "laminæ," in fact, are not continuous calcareous layers, but are in most cases really formed by numerous irregular calcareous rods or processes which are given out by the "pillars" at definite levels, and which join with one another and with the pillars to form a reticulated or porous membrane. Hence, in a typical Stromatoporoid, the last-formed concentric lamina, which constitutes the outer surface of the organism, exhibits numerous minute pores, which open internally into the uppermost "interlaminar



Fig. 114.—A specimen of a Stromatoporoid, of the natural size, showing the concentrically laminated skeleton. The under surface is concave and was probably attached to a foreign body. From the Trenton Limestone of Canada. (After Billings.)

space," and which probably served to give exit to the zoöids of the colony. The outer layer also commonly shows numerous small granules or tubercles, which are really the free upper ends of the vertical or radial pillars. These last-named structures are small calcareous columns, which have a general radial direction, and which cross the interlaminar spaces vertically and thus connect successive concentric laminæ with one another. In some cases (as in the genus *Clathrodictyon*) the pillars are merely short perpendicular processes which run from the upper surface of one lamina to the under surface of the next. In other cases (as in the genus *Actinostroma*, fig. 115, B and C) the pillars run continuously through a considerable number of laminæ. In many cases, it can also be shown

that the radial pillars contain in their interior a minute axial canal (as in *Labechia*, fig. 116, A), but there is no ground for supposing that this opened upon the surface by any aperture.

The zoöids which composed the colony of the Stromatoporoids were sometimes merely lodged in the pores which pierce the reticulated concentric laminæ, and there are no definite "zoöidal tubes" (fig. 115, A). In other cases, such tubes are present; though their recognition is not always easy, and they are often very irregular. When well developed, the zoöidal tubes are usually intersected by

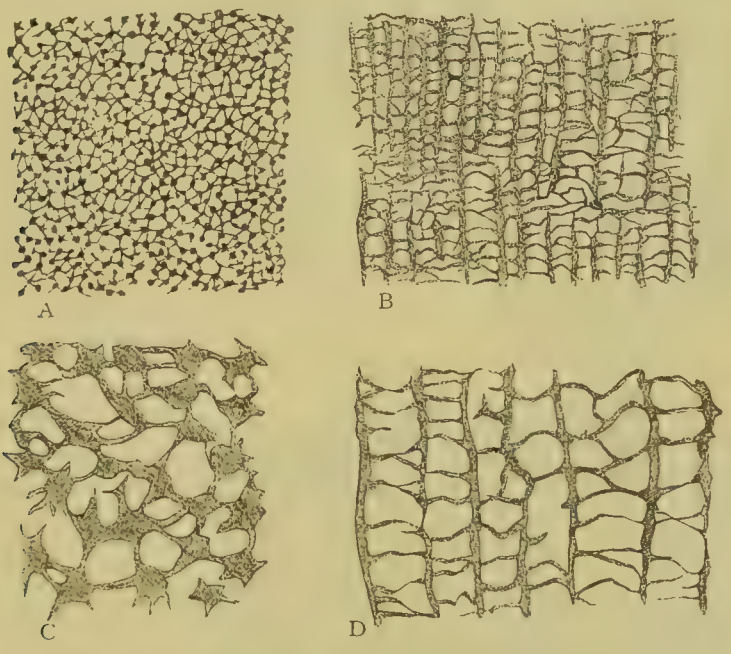


Fig. 115.—A, Tangential section of *Actinostroma intertextum*, showing the transversely-divided radial pillars and the reticulated structure of the concentric laminæ. B, Vertical section of the same, showing the radial pillars and the formation of the concentric laminæ out of processes which are given out horizontally by these. Enlarged twelve times. C and D, Parts of the same sections enlarged further. From the Silurian rocks. (Original.)

a number of transverse calcareous partitions or "tabulæ" (fig. 119, B and D). In no case are the zoöidal tubes provided with radiating vertical partitions comparable with the "septa" of corals. It would seem certain that in all the Stromatoporoids the part of the colony which would be at any given moment actually alive, must have been restricted to a thin external layer.

Among the more noticeable features presented by the Stromatoporoids are the so-called "astrorhizæ" of many types. These are stellate, often much branched, gutters or grooves which are found on the external surface of the last-formed lamina, each stellate system being placed at a little distance from its fellows. As each lamina

of the colony has at one time formed the external surface, the exterior of each exhibits astrorhizæ, as a rule, when the specimen is broken open. Very commonly, also, the astrorhizæ are placed in successive groups one above the other, those of each vertical system being united by a wall-less axial tube, which usually opens on the outer surface by an aperture, which is often placed at the summit of a conical or rounded prominence. The astrorhizal canals of the Stromatoporoids may be compared with the peculiar grooves seen on the external surface of the crusts of the recent *Hydractinia*, or with the branching and inosculating cœnosarcal canals of *Millepora*, and, like the latter, they probably transmitted stolons of the cœnosarc.

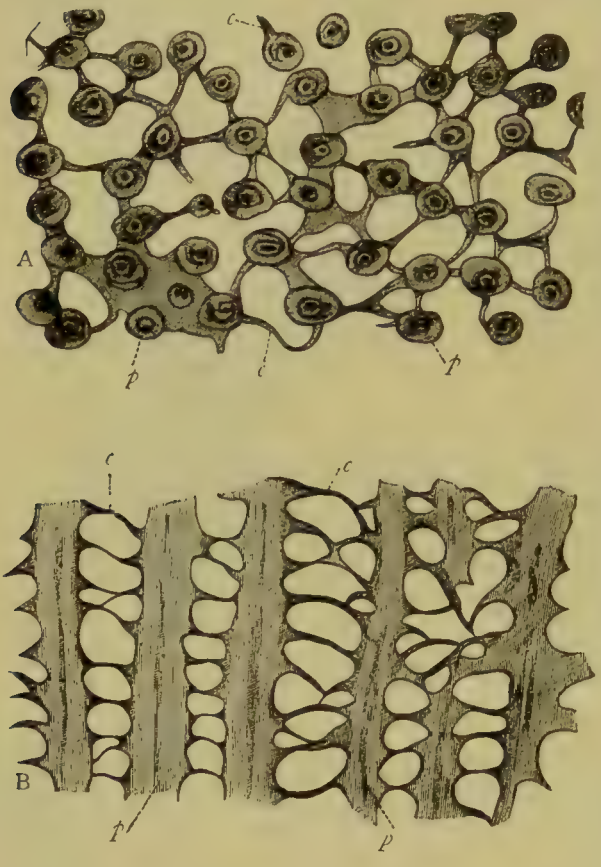


Fig. 116.—A, Tangential section of the cœnosteum of *Labechia conferta*, from the Wenlock Limestone (Silurian), enlarged twelve times. The section shows the transversely divided radial pillars (*p*), with their axial canals, and their connecting processes (*c*). B, Vertical section of the same, similarly enlarged, the letters as before. (Original.)

The Stromatoporoids may be divided into two great groups, the forms of one of these having a resemblance to *Hydractinia* in the structure of the skeleton, while those of the other possess a cœnosteum constructed more nearly after the type of that of *Millepora*. In the first of these primary sections the skeleton (as in *Actinostroma*, fig. 115, and *Labechia*, fig. 116) is composed of "radial pillars" and "concentric laminæ," which remain definitely recognisable and do not become fused with one another into a continuous reticulation. The type of this section is the genus *Actinostroma*, in which the cœnosteum is massive or laminar, often of large size, and the radial pillars are long and are continued without a break through numerous successive laminæ (fig. 115, B). The concentric laminæ

are formed by radiating processes given out in whorls at definite levels from the radial pillars, and uniting with one another in such a way as to give rise to an angular meshwork. Hence, horizontal sections of the species of this genus (fig. 115, A and C) exhibit a structure not at all unlike that of a Hexactinellid Sponge, the cut ends of the radial pillars constituting so many centres from which the horizontal processes forming the laminæ are given out in a stellate manner. The earliest types of *Actinostroma* appear in the Silurian rocks, but the genus is characteristically Devonian. In the nearly allied genus *Clathrodictyon*, the radial pillars are comparatively ill developed, and do not pass from one interlaminar space to another. The species of this genus, though not absolutely unrepresented in the Devonian, are characteristic of the Silurian period.

The singular genus *Labechia* is the type of another group of Stromatoporoids. The cœnosteum in this genus (fig. 117) is usually laminar, attached by a peduncle, and having the under surface covered with a wrinkled calcareous membrane or "epitheca." The upper surface shows no traces of pores or zoöidal apertures, but is covered with numerous blunt tubercles. Vertical sections (fig. 116, B) show that these tubercles are the free upper ends of stout radial pillars, which are connected with one another by numerous arched calcareous plates. Horizontal sections (fig. 116, A) show the cut ends of the radial pillars, united by the calcareous plates above spoken of. The pillars are hollow, with a minute axial canal, but they do not seem to be naturally perforated at their summits. In the absence of definite zoöidal pores, it must be supposed that the surface was covered with the cœnosarc, from which the polypites were budded off. The genus *Labechia* ranges from the Ordovician to the Devonian, and the allied *Rosenella* is found in the Ordovician and Silurian rocks.



Fig. 117.—A small specimen of *Labechia conferta*, from the Silurian rocks of Gotland, of the natural size, showing the epithecate under side and the tuberculate upper surface. (Original.)

In this connection a few words may be here said with regard to the extraordinary and problematical fossils from the Ordovician rocks of North America for which Mr Billings founded the genus *Beatricea*. The fossils in question have the form of cylindrical or angular stems (fig. 118), which are nearly straight, are unbranched, and may attain a length of several feet. The outer surface sometimes shows small rounded tubercles, or may exhibit minute circular apertures, the nature of which is quite uncertain. Transparent transverse and vertical sections (fig. 118, B and C) show that the fossil is principally made up of a thick outer sheath of lenticular calcareous cells

or vesicles, which are arranged in concentric layers round a large axial tube running the whole length of the organism. This axial tube is intersected by strongly curved calcareous partitions or "tabulæ"; and the vesicular tissue which surrounds it is sometimes found to be traversed by columns which radiate outwards to the circumference, and which may be compared with the "radial pillars" of *Labechia*. Upon the whole, with our present knowledge, it would

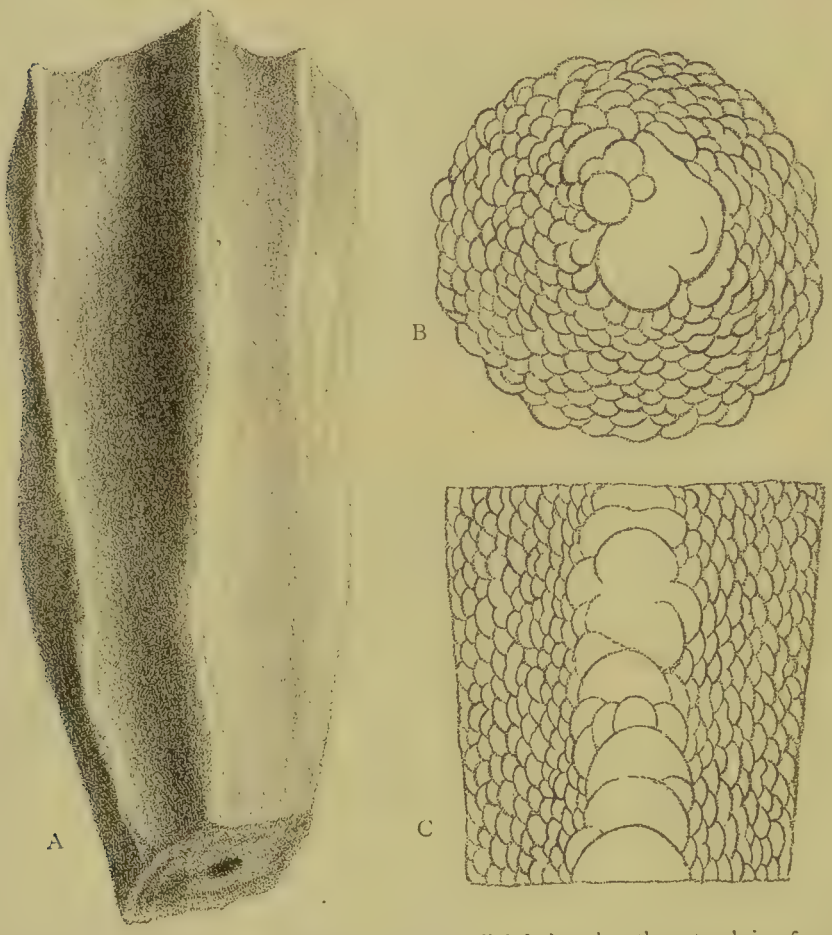


Fig. 118.—A, A fragment of *Beatricea undulata*, slightly less than the natural size, from the Ordovician rocks (Cincinnati Group) of North America. B, Cross-section, and C, Vertical section of *Beatricea nodulosa*, from the same formation, slightly enlarged. The sections show the peripheral vesicular tissue and the central tabulate tube. (Original.)

seem best to regard *Beatricea* as a very abnormal type of the Stromatoporoids, with relationships to *Labechia* and *Idiostroma*; but the position of this anomalous genus must be regarded as more or less doubtful.

The remaining forms of the Stromatoporoids present certain strong resemblances in their structure to the existing genus *Millepora*, and

differ from the types previously considered in the fact that the radial pillars and concentric laminæ are so combined with one another as to lose their distinctness as separate elements, and to become fused with one another so as to form a continuously reticulated skeleton. Moreover, the skeletal tissue has a peculiar microscopic structure, being minutely porous or tubulated (fig. 119, A and B). Definite zoöidal tubes are also present, and these are crossed by more or less

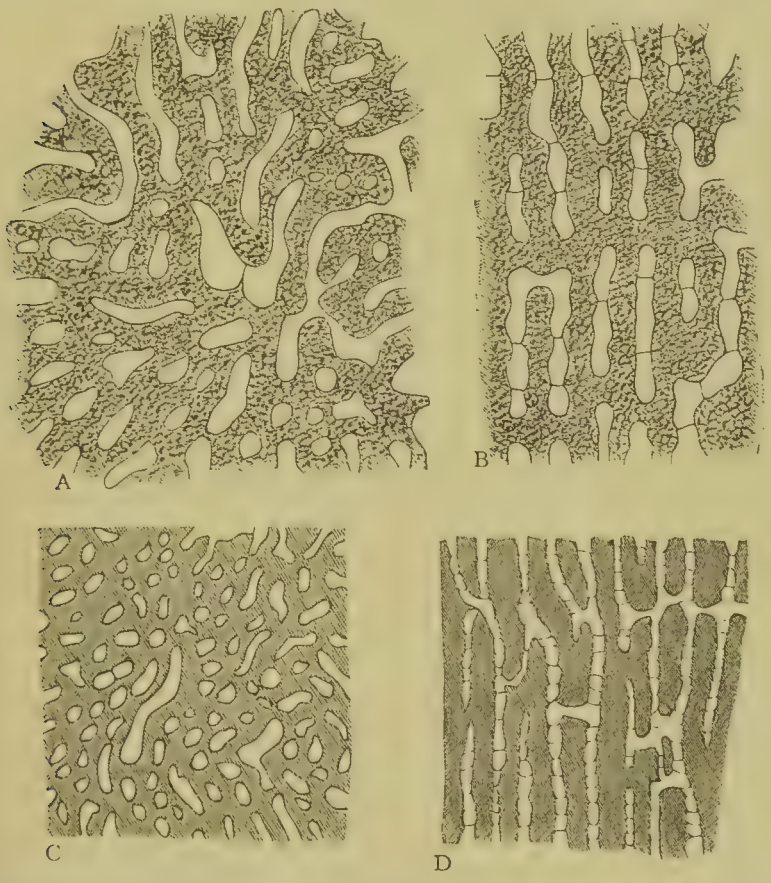


Fig. 119.—A, Tangential section of *Stromatopora Beuthii*, enlarged twelve times, showing the reticulate skeleton and the porous skeleton-fibre; B, Vertical section of the same, similarly enlarged, showing the tabulate zoöidal tubes; C and D, Tangential and vertical sections of *Stromatopora bücheliensis*, similarly enlarged. Middle Devonian. (Original.)

extensively developed transverse partitions or "tabulæ" (fig. 119, B and D). The type of this group is the genus *Stromatopora* itself, in which the cœnosteum is massive or laminar and is usually furnished with an epitheca. The skeleton is completely reticulate, the radial pillars and their connecting-processes being completely fused with one another, so as to give rise to a vermiculate tissue traversed by minute, irregular, tabulate zoöidal tubes. Very commonly, the

massive skeleton is formed of a series of thick concentric strata ("latilaminæ"), each of which is made up of subordinate concentric "laminæ." The type of this genus is the *Stromatopora concentrica* of Goldfuss, a comparatively rare species in the Middle Devonian of Germany and Britain. Upon this species Goldfuss founded the genus *Stromatopora*, but the name has been erroneously given to various Stromatoporoids of quite different affinities. Other species of *Stromatopora* are found in the Silurian and Devonian rocks; and the allied genus *Stromatoporella* appears to be principally if not wholly Devonian.

Lastly, there is a group of Stromatoporoids, represented by genera such as *Idiostroma* and *Amphipora*, in which the skeletal tissue resembles that of *Stromatopora* in its reticulated character, but the cœnosteum is cylindrical and often branched, and is provided internally with a comparatively large axial tube intersected by cross partitions or "tabulæ." The genera above-mentioned are both Devonian, and the sole known species of *Amphipora* (viz., *A. ramosa*) is an abundant and characteristic fossil in the Middle Devonian of Germany and Britain, its slender cylindrical stems occurring in great abundance in particular beds in this formation.

Before leaving the subject of the Stromatoporoids, allusion may be made to the fossils which have been described under the name of *Caunopora*. The fossils in question resemble the ordinary Stromatoporoids, and indeed *are* only Stromatoporoids of various species, with the peculiarity that the general tissue of the cœnosteum is traversed by a number of comparatively large, thick-walled vertical tubes, which open on the surface by definite round apertures. These tubes often spring at the base from horizontal stolons, and are usually connected here and there by lateral tubes of a similar structure to themselves; they usually, if not always, have funnel-shaped, or sometimes horizontal, internal calcareous partitions or "tabulæ," and they occasionally possess rows of short "septal spines." It has been shown that the same species of Stromatoporoid may occur with or without these peculiar "Caunopora-tubes," and there exists further an obvious likeness between these tubes and the corallites of such corals as *Aulopora* and *Syringopora*. Upon the whole, therefore, it may be regarded as probable, if not absolutely certain, that the fossils usually grouped together under the name of "*Caunopora*" are Stromatoporoids which in course of growth have enveloped a colony of some such coral as an *Aulopora* or *Syringopora*, the latter not being thereby killed, but continuing to grow and flourish as a "commensal" within the tissues of the Stromatoporoid.

As regards the *zoological affinities* of the Stromatoporoids, their general structure seems to render it certain that they are referable to the *Hydrozoa*, of which they must be considered to form a special and now unrepresented group. Certain forms (such as *Actinostroma* and *Labechia*) show a decided relationship with the recent *Hydractinia*: while others (such as *Stromatopora* itself) are more closely connected

with the Hydrocorallines, and especially with *Millepora*. These two groups of Stromatoporoids are, however, united by various transitional forms, and they possess structural peculiarities of sufficient importance to preclude the reference of the entire series to any existing division of the *Hydrozoa*.

As to their general *geological distribution*, the Stromatoporoids are not certainly known as occurring out of the Ordovician, Silurian, and Devonian formations. Very few forms have yet been recognised in the Ordovician rocks, but the genus *Labechia* is well represented in strata of this age. The aberrant genus *Beatricea* is also Ordovician. In the Silurian rocks, Stromatoporoids are exceedingly abundant, often entering largely into the composition of the limestones of this period. The predominant Silurian genus is *Clathrodictyon*, but the genera *Actinostroma*, *Stromatopora*, and *Labechia* are also represented. It is, however, in the Devonian rocks, and particularly in the Middle Devonian, that the Stromatoporoids attain their maximum development, the group being represented in strata of this age by numerous species of *Actinostroma*, *Stromatopora*, and *Stromatoporella*, as well as by forms of *Idiostroma*, *Amphipora*, &c. Stromatoporoids have been said to occur in the Carboniferous rocks, but the true nature of these has not as yet been satisfactorily investigated. There are also certain Secondary fossils which, on further examination, may prove to be referable to the present group.

LITERATURE OF HYDROZOA.

I. Corynida.

1. "Fossil Hydractiniæ." 'Geological Magazine,' 1872. Allman.
2. "On the close Relationship of Hydractinia, Parkeria, and Stromatopora, with descriptions of new species of the former, both recent and fossil." 'Annals Nat. Hist.,' 1877. Carter.
3. "On New Species of Hydractiniidæ, Recent and Fossil." 'Ann. Nat. Hist.,' 1878. Carter.
4. "Description of Parkeria and Loftusia." 'Phil. Trans.,' 1869. W. B. Carpenter and H. B. Brady.
5. "On the Structure and Affinities of the Genus Parkeria." 'Annals Nat. Hist.,' 1888. Nicholson.
6. "On certain anomalous Organisms which are concerned in the formation of some of the Palæozoic Limestones." (Mitcheldeania and Solenopora.) 'Geol. Magazine,' 1888. Nicholson.
7. "Ueber fossile Hydrozoen aus der Familie der Coryniden." 'Palæontographica,' Bd. 25, 1877. Steinmann.

II. Thecaphora and Graptolitoidea.

8. "Graptolites de Bohême." Barrande. 1850.
9. "Ueber Graptolithen." Scharenberg. 1851.

10. "Die Graptolithen. Versteinerungen der Grauwacken-formation. Geinitz. 1852.
11. "Graptolites of the Quebec Series." 'Descript. of Canadian Organic Remains.' Decade ii. Hall. 1865.
12. "Monograph of the British Graptolitidæ." Part i., General Introduction. Nicholson. 1872.
13. "Notes on the British Graptolites." 'Geol. Mag.,' 1873. Lapworth.
14. "On the Geological Distribution of the Rhabdophora." 'Annals Nat. Hist.,' 1880. Lapworth.
15. "On new British Graptolites." 'Annals Nat. Hist.,' 1880. Lapworth.
16. "On Scottish Monograptidæ." 'Geol. Mag.,' 1876. Lapworth.
17. "The Geology and Palæontology of the West of Scotland." 'Catalogue of the Western Scottish Fossils,' 1876. Lapworth.
18. "On the Graptolites described by Hisinger and the older Swedish Authors." 1882. Tullberg.
19. "Die Graptolithen-familie Dichograptidæ." 1885. Herrmann.

III. Trachymedusæ and Lucernarida.

20. "Ueber fossile Medusen." 'Zeitschr. für Wiss. Zool.,' 1865 and 1870. Haeckel.
21. "Ueber fossile Medusen." 'Mém. Ac. imp. de St Petersbourg,' 1871. Brandt.
22. "Om Aftryck af Medusor i Sveriges Kambriska Lager" (On Impressions of Medusæ in the Cambrian Rocks of Sweden). 'Kongl. Svenska Vetenskaps-Akad. Handlingar,' 1881. Nathorst.

IV. Hydrocorallinæ.

23. "Contributions to the Natural History of the United States." Louis Agassiz. (The animal of *Millepora* is figured, vol. ii., pl. xv., and the genus is referred to the Hydrozoa.)
24. "Observations critiques sur la classification des Polypiers paléozoiques." Compt. Rend. t. lxxx., 1875. Dollfus.
25. "Notes on Two Species of Millepora," &c. 'Phil. Trans.,' 1876. Moseley. (This memoir also contains a note on the structure of a Stylaster.)
26. "Structure of a Species of Millepora occurring at Tahiti." 'Annals Nat. Hist.,' 1876. Moseley.
27. "Preliminary Note on the Structure of the Stylasteridæ." 'Annals Nat. Hist.,' 1877. Moseley.
28 "On the Actinozoan Nature of Millepora alcicornis." 'Annals Nat. Hist.,' 1876. Nelson and Martin Duncan.
29. "On the Structure of the Stylasteridæ." 'Phil. Trans.,' 1878. Moseley.
30. "Report on certain Hydroid, Alcyonarian, and Madreporarian Corals." 'Report on the Scientific Results of the Voyage of H.M.S. Challenger,' vol. ii. 1881. Moseley.
31. "Scientific Results of the Second Yarkand Mission" (Syringosphæridæ). 1879. P. Martin Duncan.
32. "On the Genus Stoliczkaria and its Distinctness from Parkeria." 'Quart. Journ. Geol. Soc.,' 1882. P. M. Duncan.
33. "Zwei neue Anthozoen aus den Hallstädter Schichten." 'Sitzungsberichte d. k. Akad. d. Wiss. Wien.,' Bd. ii., 1865. Reuss.

V. STROMATOPOROIDEA.

34. "Petrefacta Germaniæ." Goldfuss. 1826.
35. "Ueber die Natur der Stromatoporen." Von Rosen. 1867.
36. "Die Stromatoporen des rheinischen Devons." Bargatzky. 1881.
37. "Monograph of the British Stromatoporoids." 'Palæontographical Society.' Part I. General Introduction. 1886. Nicholson.
38. "On some new or imperfectly known species of Stromatoporoids." 'Annals Nat. Hist.,' 1886, 1887. Nicholson.

CHAPTER XVI.

SUB-KINGDOM CŒLENTERATA—continued.

CHARACTERS, STRUCTURE, AND DISTRIBUTION OF THE ACTINOZOA.

THE division of the *Actinozoa* comprises the Sea-anemones, the Corals, and various allied forms, and is defined as including *Cœlenterate animals in which the mouth opens into an œsophageal tube, which in turn opens below into the general cavity of the body* ("*cœlenteric space*"). *The œsophagus is separated from the body-wall by an intervening "perivisceral space," which is divided into a series of compartments by radiating vertical membranous partitions or "mesenteries," to the faces of which the reproductive organs are attached.*

The *Actinozoa* differ, therefore, fundamentally from the *Hydrozoa* in this, that whereas in the latter the space ("cœlenteric" space) included within the body-walls is simple and undivided, and there is no proper alimentary tube, in the former there is a distinct œsophagus (fig. 120, *g*), and the general cavity of the body is divided into radial compartments by vertical membranous plates ("mesenteries").

The tissues of the *Actinozoa* consist of an external "ectoderm" and an internal "endoderm," between which is developed an intermediate layer or "mesoderm" (the "mesoglœa). The ectoderm covers the entire outer surface of the organism, and is prolonged inwards at the mouth to form the lining of the œsophageal tube, while the endoderm lines all the internal cavities of the body. Both the ectoderm and endoderm are primitively cellular, but both are liable to undergo more or less differentiation, muscular fibres, nerve-cells, thread-cells, &c., being developed in process of growth. The mesoderm is essentially composed of connective tissue, and forms an intermediate layer (the "Stütz-lamelle" of the Germans) which gives stability to the soft body of the animal.

The *Actinozoa* may be simple, as in the Sea-anemones, the organ-

ism consisting of a single "polype"; or they may be composite, the organism being composed of more or less numerous polypes connected with one another directly, or united by a common "cœnosarc."

Taking a simple Actinozoön, such as a Sea-anemone (fig. 121), as the type of the class, the body is seen to form a cylindrical tube, the walls of which are formed by the three layers above spoken of, enclosing an internal cavity (the "visceral chamber"). The base of the cylinder is usually completely closed, and often forms a muscular disc of attachment ("pedal disc"). The distal end of the cylindrical body, on the other hand, is perforated centrally by the oval fissure of the mouth, and is furnished round its margin with a series of hollow, muscular and tactile "tentacles." The mouth opens into a membranous œsophageal tube, formed by an infolding of the ectoderm and endoderm, which hangs down into the body-cavity, and terminates at some distance above the proximal extremity of the animal in a wide aperture by which it communicates freely with the general cavity of the "visceral chamber."

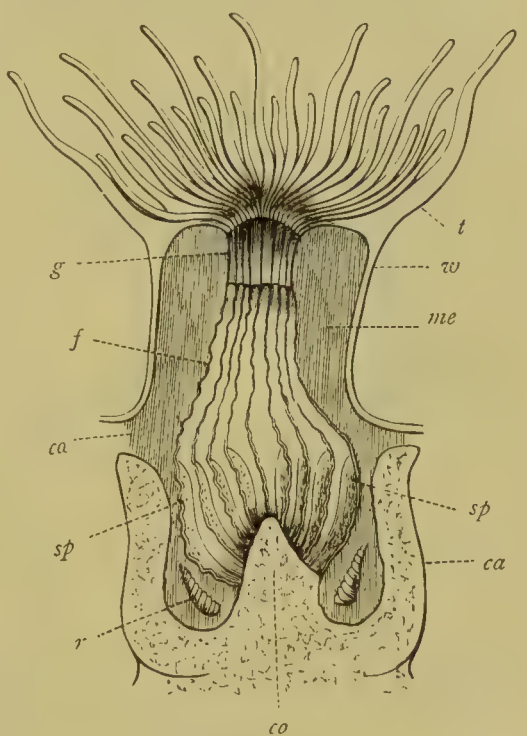


Fig. 120.—A polype of *Astroides calycularis*, a recent Zoantharian, vertically divided. *t*, Tentacles; *g*, Œsophagus; *w*, Body-wall; *me*, Flat face of a mesentery; *f*, Edge of a mesentery; *sp*, One of the calcareous "septa" of the corallum, intervening between the mesenteries; *r*, Reproductive organ; *ca*, Corallum; *co*, Columella; *cœ*, Cœnosarc. (After Lacaze-Duthiers.)

The general space ("visceral cavity") included within the body-walls is subdivided into radiating compartments by a series of vertical membranous partitions, which spring from the body-wall internally and are directed inwards, constituting what are known as the "mesenteries." Some of these partitions—known as the "principal" or "primary" mesenteries—extend all the way from the body-wall to the side of the œsophagus; and in the *Alcyonaria* all the mesenteries do so. In most cases, however, there are shorter mesenteries, which fall short of the gullet, and which are known as

"secondary" and "tertiary" mesenteries according to their relative length. Below the level of the bottom of the œsophagus the inner edges of even the principal mesenteries are free (fig. 120, *f*); and the intermesenteric compartments thus all open freely into a common space, while they may also communicate with one another by means of perforations in their bounding mesenteries, placed near the point where the latter join the upper end of the gullet. Lastly,

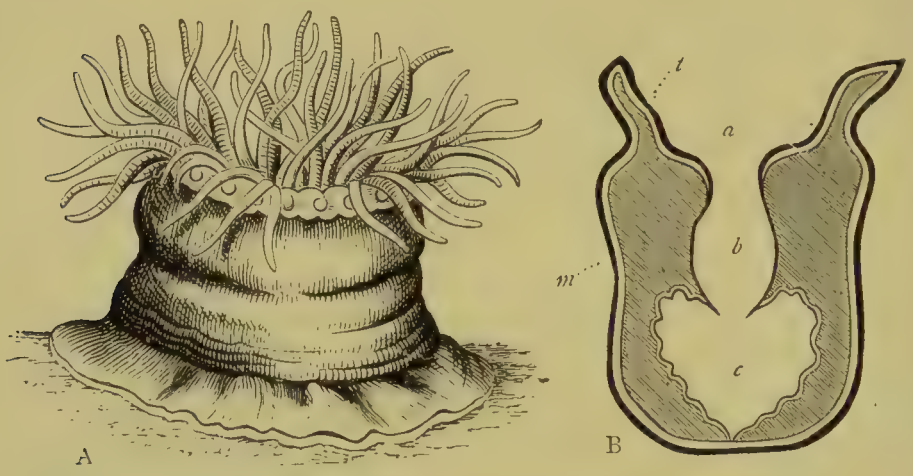


Fig. 121.—A, *Actinia mesembryanthemum*, one of the Sea-anemones (after Johnston); B, section of the same showing the mouth (*a*), the œsophagus (*b*), the body-cavity (*c*), and one of the mesenteries (*m*).

attached to the faces of certain of the mesenteries, towards the lower end of the body, are the band-like reproductive organs (fig. 120, *r*).

As regards the *development* of the mesenteries, Lacaze-Duthiers has shown that in the *Actinidæ* and in *Astroides* the first step is the appearance of a single pair of mesenteries developed at right angles to the oral fissure, nearer to one side than the other, so as to divide the body-cavity into two unequal chambers (fig. 122, 1, 1). In the larger of these chambers appear the two next mesenteries (2, 2), one on each side. Two additional mesenteries (3, 3) next appear in the smaller chamber, this making in all *six* mesenteries; but this condition is evanescent, and two further septa (4, 4) are developed on the opposite side of the first-formed mesenteries to the third pair. At this stage, therefore, there are *eight* mesenteries in all (fig. 122); but two further pairs of mesenteries are produced, raising the number to *twelve*, and completing the series of the "principal" mesenteries.

According, therefore, to the observations of Lacaze-Duthiers, the twelve "principal" mesenteries of *Astroides* are developed in six pairs, which are produced independently and at separate times; and this arrangement seems to hold good in the typical Sea-anemones. The two pairs of "principal" mesenteries which correspond with the opposite extremities of the longitudinal mouth, are known as the "directive" mesenteries. The twelve mesenteries which succeed the twelve "principal"

mesenteries, are developed in pairs in the interspaces between the six pairs of the latter, and additional pairs may be subsequently developed in a similar manner in cycles; but no new mesenteries are produced in the chambers included between the two laminæ which form each pair of "principal" mesenteries.

On the other hand, according to the views of Milne-Edwards and Haime, the mesenteries of the Sea-anemones, and of the ordinary Zoantharian Corals, are developed in a primary cycle of six, to which a second cycle of six is soon added. Should a further development of mesenteries take place, a third cycle of twelve is produced, the new laminæ being formed simultaneously in the intervals between those already in existence; and any further production of mesenteries is

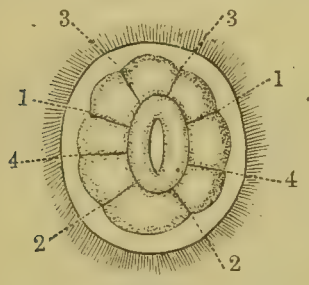


Fig. 122.—Embryo of a Sea-anemone (*Actinia mesembryanthemum*), in which the first eight septa have been developed (after Lacaze-Duthiers). The numerals indicate the order in which primitive septa make their appearance.

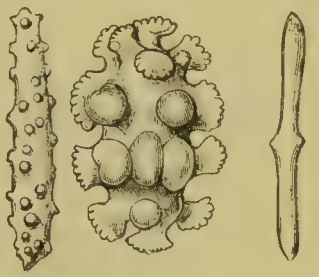


Fig. 123.—Calcareous spicules ("dermosclerites") of the *Gorgonidæ*, greatly enlarged. A, *Gorgonia radula*; B, *Sclerogorgia suberosa*; C, *Melithæa ochracea*. (After Kölliker.)

supposed to take place in obedience to the same general law. So far as the later cycles of septa in the *Hexacoralla* are concerned, the general law has been laid down by von Koch that each new septum is produced in the interspace between two older ones, and the septa of each successive cycle are produced, approximately, simultaneously.

In certain of the *Actinozoa*, such as the Sea-anemones, and the *Ctenophora*, the body remains permanently soft; but most of the animals belonging to this class produce hard structures, which vary much in different cases, and are known by the general name of the "corallum." The simplest form of the corallum is that of detached microscopic "spicules" of carbonate of lime, which are more or less largely developed in the soft tissues, but do not unite with one another to form a coherent skeleton. Such spicules are of common occurrence in the Alcyonarians, and their shape (fig. 123) varies greatly in different types. They are most abundantly developed in the cœnosarc, but may also be present in the walls of the polypes. Though usually permanently separate, the spicules may become so far fused with one another as to give rise to a coherent external skeleton, as occurs in the Organ-pipe Corals (*Tubipora*).

In other cases, as in the Red Coral (*Corallium*), the spicules become fused so as to form a solid cylindrical calcareous axis, which occupies the centre of the cœnosarc (fig. 124). Such a cœnosarcal axis is produced independently of the polypes of the colony, and constitutes what is known as a "sclerobasic" corallum. The form of the sclerobase or axial corallum is simple or branched, in accordance with the undivided or divided condition of the cœnosarc; and its precise structure is very variable. In *Corallium* it is formed of microscopic spicula united by a general calcareous matrix; but in other cases the uniting matrix may be horny, while in the *Anti-*

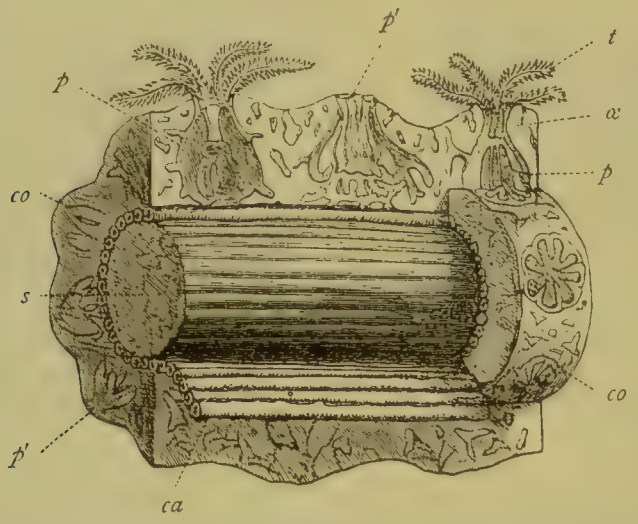


Fig. 124.—A portion of a colony of Red Coral (*Corallium rubrum*), longitudinally divided, and having part of the cœnosarc with its embedded polypes removed. (After Lacaze-Duthiers.) *co*, Cœnosarc, with its embedded polypes, its outer portion traversed by reticulate canals; *s*, Sclerobasic corallum, grooved for the reception of a series of longitudinal cœnosarcal canals (*ca*); *p p*, Polypes having their tentacles (*t*) protruded; *α*, Gullet; *p' p'*, Polypes retracted within the cœnosarc.

pathidæ and in many of the *Gorgonidæ* the sclerobase is not formed by the fusion of calcareous spicules, but is the result of the secretion of horny matter in successive concentric layers.

In the great majority of the coralligenous *Actinozoa* the corallum is calcareous, and is not formed by the fusion of definite "spicula," but is the result of the secretion of carbonate of lime by the outer surface of the ectoderm. Such a corallum has been commonly spoken of as "sclerodermic." The actual calcareous tissue ("sclerenchyma") which constitutes an ordinary Madreporarian coral has a peculiar microscopic structure, appearing as if formed of bundles of minute calcareous fibres, and commonly having a sub-crystalline character. When these bundles of fibres are cut across transversely (fig. 125, A), they give rise to a characteristic stellate structure, which in some cases (*e.g.*, *Stylophora*, *Pocillopora*, &c.) is of a very regular

nature. In many instances the entire corallum of a Madreporarian consists of the ordinary fibrous sclerenchyma just alluded to. It is not unusual, however, to find that in progress of growth the original skeleton becomes thickened, and its internal cavities more or less restricted, by a deposition of carbonate of lime of secondary origin. This secondarily-formed calcareous tissue has been termed "stereoplasma" by Lindström, and it is often of lighter colour than the sclerenchyma of the original skeleton (fig. 125, B), or is otherwise distinguishable from the latter.

An ordinary sclerodermic coral may consist of a single cuplike structure corresponding with a single polype, or of several such,

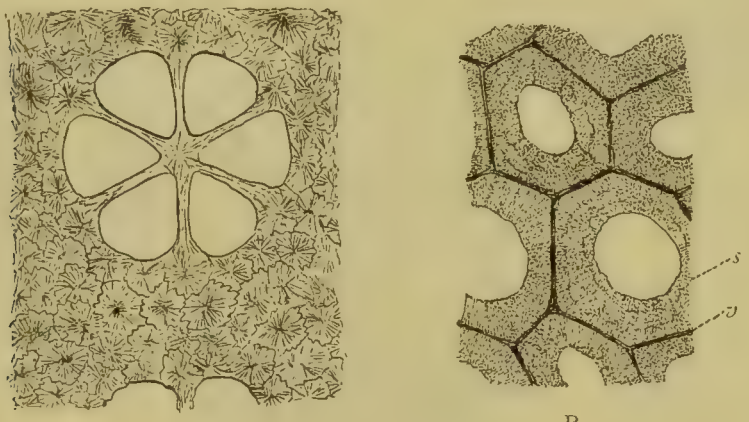


Fig. 125.—A, Portion of a tangential section of the corallum of the recent *Stylophora palmata*, enlarged, showing the fibro-crystalline structure of the sclerenchyma. B, A few corallites of *Pachypora Nicholsoni*, Frech, transversely divided and considerably magnified, showing the primordial wall (*v*) and the dense lining of secondary "stereoplasma" (*s*). From the Middle Devonian of Gerolstein. (Original.)

springing directly from one another, or united by a common calcareous tissue ("cœnenchyma") corresponding with the cœnosarc of the colony.

A typical simple sclerodermic corallum (fig. 126) is secreted by a single polype, and its structure presents an obvious correspondence with that of the animal which produces it. It is generally more or less conical in shape, or sometimes discoid, and consists of an outer wall and included space. The wall corresponds with the lower part of the column of the polype, and is known as the "theca." It may be very imperfect, or may be strengthened by a secondary calcareous investment ("epitheca"). The theca encloses a space which corresponds with the lower part of the body-cavity of the polype, and is known as the "visceral chamber." Superiorly the theca terminates in a shallower or deeper, cup-shaped depression, which contains the œsophagus of the polype, and is known as the "calice." Below

the calice, the visceral chamber is subdivided into a number of vertical compartments ("loculi") by a series of upright calcareous partitions or "septa," which spring from the inner surface of the theca, and are directed inwards towards the centre. The septa are calcifications formed within the intermesenteric chambers (fig. 120, *sp*), so that each septum is placed between two mesenteries and underneath a tentacle, and the total number of the septa is equal to that of the mesenteries. The septa likewise increase in number with the increasing growth of the polype, as the mesenteries do; and, like the latter, they vary in their width, so that they are often spoken of as "primary," "secondary," and "tertiary" septa.

The septa of both recent and fossil corals, when examined in cross-sections, commonly show a composition out of two lamellæ of dense,



Fig. 126.—*Caryophyllia borealis*. A simple sclerodermic Coral, twice the natural size. (After Sir Wyville Thomson.)

usually light-coloured sclerenchyma ("stereoplasma"), separated by a median, generally dark line (fig. 127).

This central dark line (the "Primärstreif" of the Germans) has been regarded as a mere line of calcification; but it seems to be really a distinct median lamella, representing the primordial septum, while the lateral layers of stereoplasma are of secondary origin. In some cases (as in *Caryophyllia borealis*, fig. 127, A), it appears that this central plate is itself double, and it is probable that it is always so in origin, even though its component elements become completely fused in process of growth.[1] In other cases (as in *Heliophyllum* and its allies), the septa

[1] Hinde has clearly shown that the primary lamella of the septum is really double in the genus *Septastræa*, and a somewhat similar structure of the septa seems to obtain in the recent genus *Flabellum*.

appear to consist principally, or only, of the thin primitive central lamella, no secondary layer of stereoplasma, or but a very imperfect one, being developed. In such cases, the outer wall of the coral is also very thin (fig. 128, B). Where secondary stereoplasma is well developed, the thickened outer ends of the septa usually become fused with one another, so as to form a more or less dense outer investment to the visceral chamber. Sometimes (as in *Streptelasma*, fig. 127, B), the external wall of the corallum seems to be formed wholly by the thickened outer ends of the septa; but in many forms the primitive theca can be recognised in the substance of the outer investment as a thin dark plate (fig. 127, *t*) formed by lateral outgrowths from the primordial septa. Hence in such cases the peripheral ends of the septa continue to grow outwards subse-

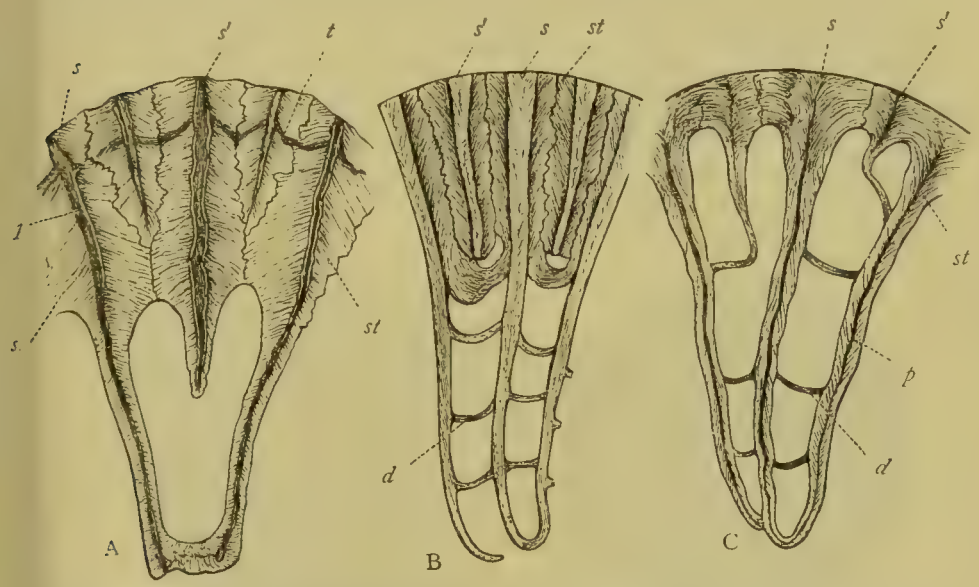


Fig. 127.—A, Portion of a cross-section of the recent *Caryophyllia borealis*, enlarged to show the structure of the septa. B, A similar preparation of *Streptelasma corniculum*, Ordovician, N. America. C, A similar section of *Zaphrentis Enniskilleni*, Carboniferous. *p*, Dark line occupying the middle of the septum; *st*, Layer of stereoplasma; *t*, Theca, formed by out-growths from the outer ends of the septa; *s*, Septum of the first order; *s'*, Septum of the second order; *d*, Dissepiments. (Original.)

quently to the formation of the original theca; each septum thus coming to consist of an intrathecal and an extrathecal portion.

In some corals (as, for example, in *Pholidophyllum*), it can be clearly shown that the septa are made up of calcareous trabeculæ or spines (the "Vertical-leisten" of the Germans), which are directed upwards and inwards towards the axis of the corallum, and which become united with one another directly or by means of secondary sclerenchyma. In *Heliophyllum*, *Crepidophyllum*, *Phillipsastræa*, and other allied genera of Palæozoic corals, these oblique septal trabeculæ are greatly developed, and are not obscured by the development of lateral layers of stereoplasma. Hence in these genera cross-sections of the septa (fig. 128, B) exhibit characteristic thickenings or cross-bars, which have been termed "carinæ," and which are the result of the intersection of the septal spines just spoken of, while the free edges of the septa are furnished with pointed projections or teeth.

In many composite corals calcareous structures, as will be subsequently seen, are commonly developed externally to the thecæ of the polypes, constituting what is known by the general name of "peritheca" or "exotheca." In a simple sclerodermic coral, such as we are here considering, the only exothecal structures are the so-called "costæ." These are vertical ridges on the exterior of the corallum, which correspond with the septa, and which, in fact, are the exothecal edges of the septal laminæ. In some cases, however, we meet with similar vertical ridges ("rugæ" or "pseudocostæ") on the exterior of the theca which do not correspond with the septa within, in many instances alternating with the latter; but the true nature of these is not clear. The costæ, when present, vary much as to their relative distance apart, their breadth, their solidity, and their ornamentation with tubercles, granules, or teeth.

In the interior of the corallum various "endothecal" structures may be developed, all of which may be regarded as essentially produced by modifications of, or outgrowths from, the septa. In many

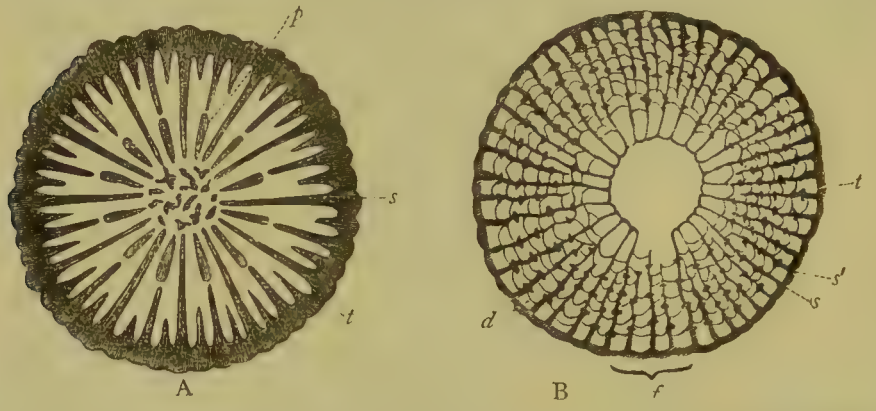


Fig. 128.—A, Transverse section of a simple Zoantharian Coral (*Caryophyllia Bowerbanki*), enlarged. (After Milne-Edwards and Haime.) *t*, Theca; *s*, One of the primary septa; *p*, One of the "pali." In the centre is seen the irregular "columella." B, Transverse section of a Rugose coral (*Crepidophyllum subcæspitosum*), enlarged four times (Original). *t*, Theca; *d*, "Dissepiments"; *s*, One of the first order of septa; *s'*, One of the second order of septa; *f*, "Fossula." In the centre of the coral is a space occupied by tabulæ.

corals the septal laminæ themselves are more or less rudimentary, and may be represented only by vertical rows of spines (as in *Favosites*) or by mere longitudinal striæ (as in species of *Cystiphyllum*). When the septa have the form of complete calcareous lamellæ, they may terminate internally by free edges, and the centre of the visceral chamber may be completely vacant. In other cases, narrow vertical plates which are known as "pali" (fig. 128, A) are developed at the inner ends of certain of the septa, and have the appearance of being continuations of the latter, though detached from them. When a "columella" is present, the inner edges of the pali are united with

this. The "columella" is the general name given to certain axial structures which are commonly developed from the centre of the base of the visceral chamber. The structure of the columella varies in different cases, but it extends, typically, from the floor of the visceral chamber to the bottom of the calice, into which it projects for a greater or less distance; and the principal septa are often more or less closely connected with it. In some cases, the columella is a solid calcareous rod, or it may be made up of reticulated calcareous tissue (fig. 128, A) or of twisted calcareous fibres, while in other instances its structure is even more complicated.

Theoretically, the "interseptal loculi" are vacant spaces or vertical compartments, bounded laterally by the septa, and extending from the lower and lateral surfaces of the theca to the floor of the calice. In practice, however, the continuity of the interseptal loculi is usually more or less interfered with by the development of one or more of the structures known as "synapticula," "dissepiments," and "tabulæ." The "synapticula" are transverse calcareous bars which stretch across the interseptal loculi, perforating the mesenteries, and

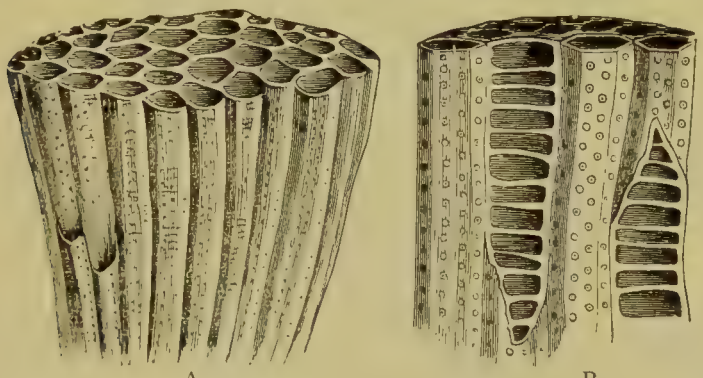


Fig. 129.—A, Portion of the corallum of *Favosites favosa*, of the natural size; B, Portion of four corallites of *Favosites Gothlandica*, enlarged, showing the tabulæ.

form a sort of trellis-work uniting the faces of adjacent septa. They are specially characteristic of the *Fungidæ*. The structures known as "dissepiments" are present in the majority of corals, and have the form of incomplete, oblique or approximately horizontal plates, which stretch between adjacent septa, and break up the interseptal loculi into secondary compartments or cells. Lastly, the "tabulæ" may be regarded as highly developed dissepiments, and, like them, are approximately horizontal, as a rule at any rate. They differ from the dissepiments in the fact that they cut across the interseptal loculi at the same level. When fully developed (fig. 129, B), they are transverse plates, which extend completely across the visceral cham-

ber, and divide it into a series of storeys placed one above the other, the only living portion of the coral being above the last-formed tabulæ. In some cases, the tabulæ are "incomplete," and are merely flat tongue-shaped plates which extend from the inner surface of the theca transversely into the visceral chamber. In other cases (as in *Michelinia*), the tabulæ are imperfect, and become united with one another so as to form a sort of vesicular tissue. In still other cases (as in *Syringopora*) the tabulæ are funnel-shaped, and fit into one another from above downwards.

As regards the process of *development*, the ordinary sclerodermic corallum is the result of the secretion of carbonate of lime by a special layer of ectodermal cells ("calicoblast layer," fig. 130, *ca*), and is therefore truly external to the body of the polype by which it is produced. If the formation of the corallum be observed in the embryo of *Astroides*, it is found that the first step is the secretion of a ring-shaped "basal plate" (fig. 130, *ba*) between the lower surface of the polype and the substance to

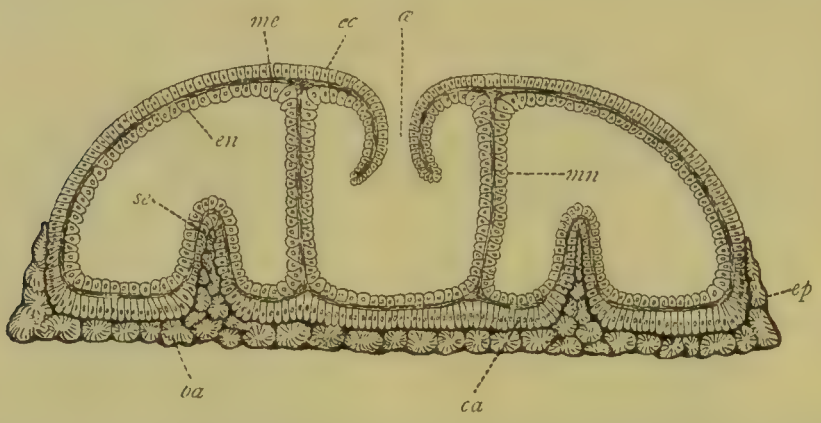


Fig. 130.—Diagrammatic vertical section of a young polype of *Astroides calicularis*, showing the formation of the corallum, greatly enlarged. *ba*, Basal plate, produced by a special layer of ectodermal cells (*ca*); *ep*, Lateral wall of the corallum; *se*, One of the septa, pushing before it a fold of the entire body-wall; *ec*, Ectoderm; *en*, Endoderm; *me*, Mesoderm ("supporting lamella"); *mn*, Mesentery; *œ*, Gullet. (Slightly altered from Bourne, and based on a figure given by von Koch.)

which it has attached itself. The formation of the septa is subsequent to that of the basal plate, these structures appearing as radially-disposed ridges or folds of the base of the polype, each fold (fig. 130, *se*) being composed of the three constituent layers of the body-wall. The septa are thus, like the basal plate, really *external* to the polype; but in process of growth they carry up with them the folds of the body-wall by which they are covered, and they ultimately come to project into the inter-mesenteric chambers, and to have all the appearance of being internal structures.

The *theca* is not an independent structure, as is the basal plate, but seems to be usually the result of the bifurcation of the peripheral ends of the septa, and the lateral fusion of these (fig. 127, A, *t*). In some cases the external investment of the corallum seems to consist solely of the thickened outer ends of the septa (as in *Streptelasma*, fig. 127, B); but in

other cases there is present, in addition, a secondary calcareous membrane, which is known as the "*epitheca*," and which appears to be secreted by the reflection of the ectoderm over the upper part of the corallum. The "*dissepiments*," which are present in the interseptal loculi of most corals, are secreted by the ectodermal cells ("calicoblasts") of what were "originally the interseptal parts of the base of the polype" (Bourne). The soft parts of the polype thus always lie above the last-formed dissepiments, and the spaces between the latter and the theca are not occupied by soft tissues of any kind.

In connection with the preceding, a few words may be said as to the relations of the polype to the corallum which it secretes. As has been

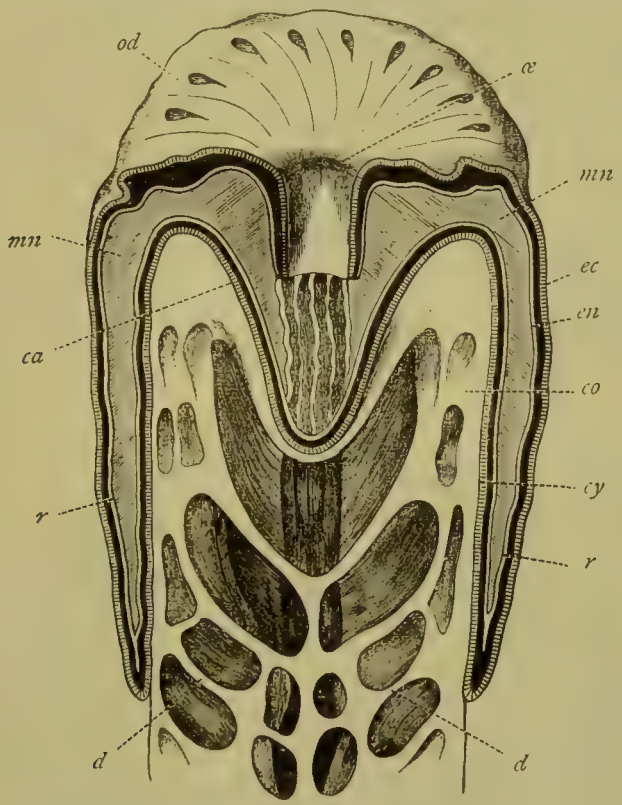


Fig. 131.—Diagrammatic vertical section of *Mussa corymbosa*, showing the relations of the polype to the corallum. *od*, Oral disc of the polype; *œ*, Œsophagus, with the free edges of the mesenteries seen below its inferior end; *mn*, Flat surface of a mesentery; *ec*, Ectoderm (cross-shaded); *en*, Endoderm (unshaded), the dark line between this and the ectoderm representing the mesoderm; *ca*, Special ectodermal layer ("calicoblast layer") secreting the corallum (*co*); *d*, Dissepiments; *r r*, Inversion of the polype constituting the "Randplatte." (Slightly altered from Bourne.)

seen, the corallum is of ectodermal origin, and is therefore really external to the polype. In process of growth, however, the corallum becomes pushed up into the polype from below, so to speak, and thus comes to be apparently situated within the polype. What actually happens, as shown in the accompanying diagram (fig. 131), is that the polype becomes inverted over the corallum, so as to form a layer *external* to the theca, which von Heider has spoken of as the "Randplatte." Thus a portion

of the polype comes to lie *external to the theca*, while a portion lies within the latter. It follows from this that the general body-cavity or "cœlenteric space" is divided by the theca into two parts, of which one is intrathecal, while the other is extrathecal, the latter being divided into chambers by mesenteries, just as the former is. [According to von Koch, the originally continuous mesenteries are cut into two by the fusion of the peripheral ends of the septa to form the theca, each mesentery thus becoming divided into an extrathecal and intrathecal portion.] Above the lip of the calice, the extrathecal and intrathecal portions of the cœlenteric space communicate with one another. It is the extrathecal portion of the polype which forms the "Randplatte" (fig. 131, *r r*); and the so-called "epitheca," when present, seems to be formed "from the free edge of the soft tissues on the exterior of the corallum, as they retreat farther and farther from the original surface of attachment" (Bourne). In composite corals the "cœnosarc" is the result of the coalescence and union of the "Randplatten" of adjacent polypes; and the general calcareous tissue ("cœnenchyma") which unites the various corallites is secreted by the cœnosarc. Where a cœnenchyma is present, the extrathecal portions of the mesenteries are awanting.

The above gives the general structure of a typical simple sclerodermic corallum, as secreted by a single polype. A *compound* sclerodermic corallum is the aggregate skeleton produced by a colony of such polypes, and varies in form and size according to the characters of the colony by which it is produced. In general, such

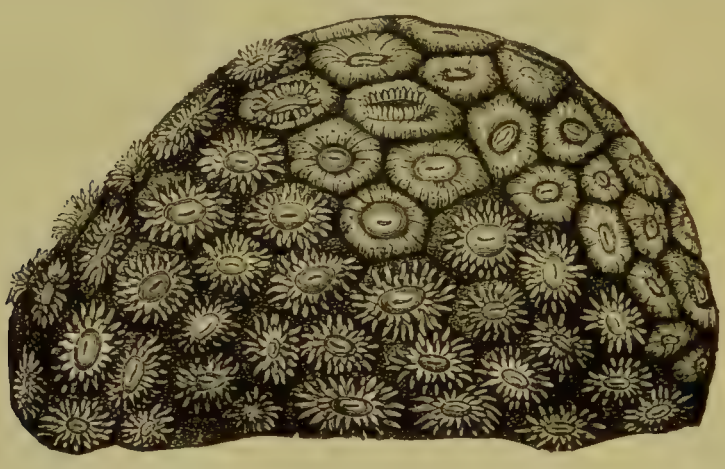


Fig. 132.—*Astræa pallida*, a compound sclerodermic Coral, in its living condition. (After Dana.)

a colony consists (fig. 132) of a number of polypes, which may spring directly from one another, or may be united by a common flesh or cœnosarc; and corresponding elements are found in the corallum. In the former instance, the compound corallum consists of an assemblage of separate "corallites," as the skeletons of the individual polypes are called, these being united with one another directly and in various ways. In the latter instance, the

corallum consists of a number of "corallites" together with a common calcareous basis or tissue, which unites the various corallites into a whole, is secreted by the cœnosarc, and is known as the "cœnenchyma."

The corallites of a composite sclerodermic coral are essentially similar in structure to a simple corallum, such as has been previously described. The "cœnenchyma" is the name given to all those calcareous structures which may unite the different corallites with one another, and which is, therefore, of "exothecal" or "perithecal" origin; and its nature varies greatly in different cases. Most usually, however, the cœnenchyma consists either of simply porous or of compact sclerenchyma; though it may have the form of a reticulated or vesicular tissue. In many of the composite coralla, the corallites composing the colony are also invested inferiorly and laterally by a general calcareous membrane or "epitheca," which is common to the entire growth.

A compound corallum is, of course, primitively simple, and it becomes composite either by budding or by cleavage of the original polype, the following being the principal methods in which this increase is effected.

1. *Lateral or parietal gemmation.*—In this mode of increase the original polype throws out buds from some point on its sides between the base

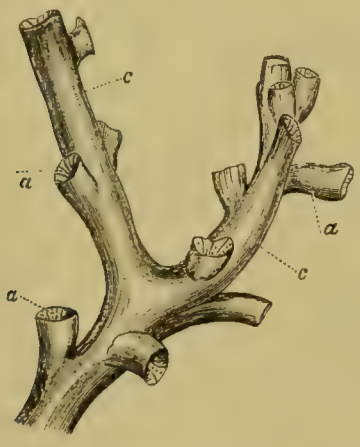


Fig. 133.—A branch of the recent *Dendrophyllia nigrescens* showing lateral gemmation. *a*, A corallite; *c*, Cœnenchyma.



Fig. 134.—Calicular gemmation as seen in *Lonsdaleia floriformis*. Carboniferous.

and the circle of tentacles, and these buds, on becoming perfect corallites, may repeat the process. Commonly the new corallites tend to diverge from one another, the resulting form of corallum being dendroid or branched. In other cases the new corallites grow up side by side, and in contact with one another, the corallum thus becoming massive or "astræiform." Composite corals produced by lateral gemmation may have the corallites directly connected with one another, or united by a more or less copious "cœnenchyma" (fig. 133).

2. *Calicinal or calicular gemmation.*—This consists in the production of buds from the calicine disc of the parent corallite, which may or may not continue to grow thereafter, whilst the new corallites thus produced generally repeat the process. The simplest form of calicular budding is seen in some of the Rugose corals (species of *Cystiphyllum*, *Heliophyllum*, &c.), where the calicine disc gives off but a single bud, which may repeat the process indefinitely, till the corallum presents the appearance of a succession of inverted cones placed one above the other, only the uppermost of these being actually alive. It is not clear, however, that the phenomena here alluded to are really the result of budding, in the proper sense of the term. It is not clear, namely, that the original polype produces a calicine bud which kills its parent; and another explanation of the observed facts would ascribe them rather to a process of "rejuvenescence" on the part of a single polype. On this view, the original polype undergoes periodic contraction and partial death, only the central part of the animal retaining its vitality. Each period of contraction is, however, followed by one of active growth, and the coral thus comes ultimately to assume the form of a succession of inverted cones.

In the more genuine forms of calicular budding, on the other hand, the form of the corallum varies according as the buds spring from the margins or centres of the calices, and as the new corallites remain free or become united with another. In one form of the process, characteristic of certain Palæozoic corals, the original polype throws up from its calicine disc one or more new corallites, which kill the parent. These, in turn, produce others after a similar fashion, till the entire corallum assumes the form of an inverted pyramidal mass resting upon the original budding polype (fig. 134).

3. *Intermural gemmation.*—This mode of budding is seen in the *Favositidæ* and in other extinct corals, and consists in the production of new corallites from the lip of the calicine wall of a pre-existing corallite, instead of from the actual calice itself. Hence in cross-sections of such corals the new corallites appear to be wedged in at the angles of junction of the old corallites (fig. 135, A), and it is not possible to determine from which of the tubes concerned the new bud has been given off. In long sections, again, the new corallite appears as if produced by the splitting of the conjoined wall of two adjacent corallites (fig. 135, B).

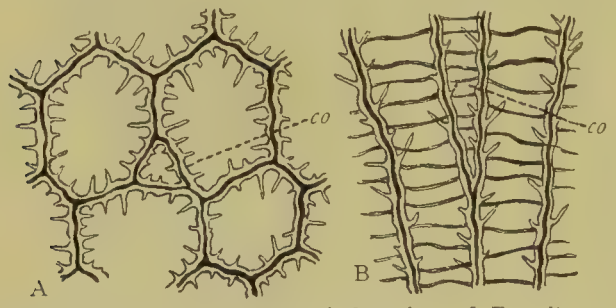


Fig. 135.—Transverse and vertical sections of *Favosites*, enlarged, showing intermural budding. *co*, A young corallite. (Original.)

4. *Basal or stolonal gemmation.*—This mode of increase is specially characteristic of the Alcyonarians, though not confined to these. In this method the original polype sends forth from its base creeping prolongations or "stolons" (fig. 136), from which new corallites are produced. In other cases the same result is attained by the budding of new corallites from a basal laminar expansion. In either case, the youngest corallites are necessarily those nearest to the periphery of the colony.

5. *Fission.*—Fissiparous multiplication commences by the partial

cleavage of the parent polype, the process of division commencing with a constriction of the oral disc, which gradually deepens till the original animal becomes divided into two more or less completely separate polypes, which, however, remain connected proximally. The process is not sharply distinguishable from gemmation, and the form of corallum produced thereby varies greatly in different cases. In many instances the corallites produced by fission may be divided for a considerable distance, remaining connected by the basal portion of the original polype only, the resulting corallum being of a "cæspitose" or tufted form, and consisting of short diverging pairs of branches, of which each pair represents the division of a single corallite. In other cases, the separation of the secondary polypes is very imperfect, and the corallum tends to assume a massive or lamellar form. In such cases the calices form continuous rows, with more or less clearly distinguishable centres, and the calicine furrows are often winding and contorted, as seen in the familiar Brain-corals (*Mæandrina*).

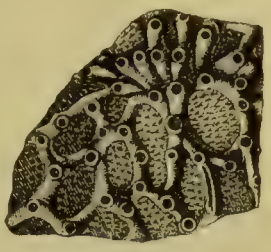


Fig. 136.—*Aulopora serpens*. Devonian.

In such corals as *Chætetes* (fig. 137), the fissiparous development of the new corallites can be generally recognised in sections without

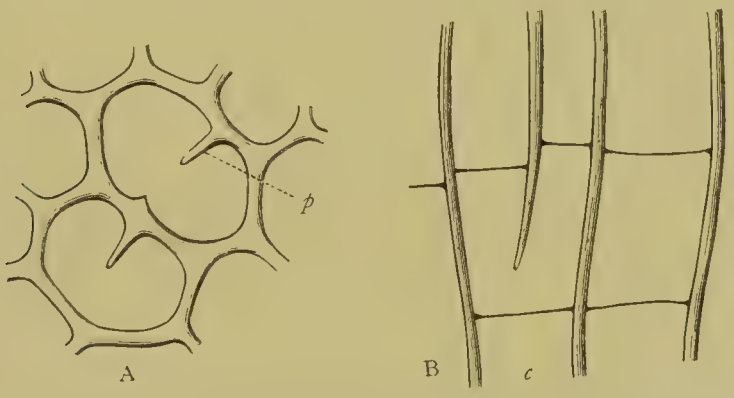


Fig. 137.—Sections of *Chætetes septosus*, from the Carboniferous rocks, enlarged to show fission of the corallites. A, Cross-section of a few corallites, some of which show the commencing fission of a tube by the development of an internal longitudinal partition (*p*); B, Vertical section, showing a single corallite (*c*) splitting into two. (Original.)

difficulty. The commencing fission of a corallite is marked by the development of an internal vertical partition, which is at first incomplete, and which therefore appears in transverse sections as an inwardly directed tooth-like process (fig. 137, A, *p*), looking like a septum. A corresponding partition is then developed opposite to the first one, and by the inward growth and final junction of these, the original tube is ultimately divided into two. In longitudinal sections (fig. 137, B), the fission of a corallite is marked by the appearance of a longitudinal partition in the interior of a tube, which thus becomes divided into two—the two new corallites being at first of small size, but gradually assuming their full dimensions.

As regards the *classification* of the *Actinozoa*, no arrangement that has yet been proposed can be regarded as more than provisional, the true affinities of various important fossil groups being still uncertain. Usually the *Actinozoa* have been divided into the four orders of the *Zoantharia*, *Alcyonaria*, *Ctenophora*, and *Rugosa*. The first three of these divisions are largely represented by living forms, and may be regarded as essentially natural groups; but the division of the *Rugosa* is certainly unnatural, and cannot be retained in its old sense. With our present knowledge—derived wholly from the skeletal structures—it is not possible to speak positively as to the precise relationships of many of the organisms included in the old group of the *Rugosa*. There is no good reason for separating certain of the so-called Rugose Corals from existing groups of the *Zoantharia Aporosa;* but it would not appear to be expedient, in the meanwhile at any rate, to refer the whole of the *Rugosa* to the above-mentioned division of the Madreporarians. The three principal groups of the *Rugosa*—viz., the Cyathophylloids, Zaphrentoids, and Cystiphylloids—are closely connected with one another, and have certain peculiar features of their own. For the reception of these, therefore, it seems to be best, provisionally at any rate, to retain the general name of *Rugosa*, but to regard the forms in question as constituting a special section of the Madreporarians rather than a distinct order.

As regards their general *distribution in space*, all the recent *Actinozoa* are inhabitants of the sea, and there is no reason to suppose that any of the fossil forms were other than marine. The coralligenous forms, generally spoken of as "Corals," are partly inhabitants of deep water, partly shallow-water types; and the latter are well known as giving rise in warm seas, and under suitable conditions, to those great aggregations of coral which are known as "coral-reefs." It is not necessary to consider here the general phenomena of existing coral-reefs, or to enter into a discussion of the vexed question as to the laws and conditions under which the various forms of these structures are produced. A few words may be said, however, as to the nature of the materials which actually form a recent coral-reef, as this is a point which has important geological bearings. In the first place, though Corals properly so called are the principal agents concerned in the construction of a coral-reef, they are not the only ones, a very important part in the formation of the reef being played by other organisms which secrete a calcareous skeleton. Thus, the materials composing a coral-reef are largely the result of the accumulation of the calcareous skeletons of animals other than corals, and particularly of the Hydrocorallines and the Molluscs; while the calcareous *Algæ* (Nullipores) take an important part in the formation of some reefs. Again, it is only a portion—chiefly the outer edge—of a modern coral-reef which is actually composed of living corals,

growing in place; and a large portion of all reefs is formed by calcareous deposits of a fragmental character, which have been produced by the action of the sea upon the reef, and which are therefore essentially made up of larger or smaller pieces of coral mixed with the entire or broken skeletons of other lime-secreting organisms. Lastly, the materials composing a coral-reef are liable to undergo more or less extensive secondary changes caused by the continued percolation through them of water, these changes being in the direction of a more or less complete crystallisation and of a consequent obliteration of the original organic structure of the rock.

Essentially, therefore, a modern coral-reef is composed, on the one hand, of more or less extensive calcareous masses formed by *the growth in place of corals* associated with other lime-secreting organisms, and, on the other hand, of purely mechanical deposits *produced by the wear and tear of the preceding*. As it is known that the reef-building corals do not thrive at depths greater than about thirty fathoms, it is certain that the portions of the reef actually formed of corals which have grown in place must have originated in quite shallow water. On the other hand, the detrital deposits formed by the degradation of the original reef form a belt on the flanks of the latter, and may extend into comparatively deep water. Moreover, the portions of the reef which are of mechanical origin may considerably exceed in amount those which are due to the direct growth of the corals themselves.

The following are the more important kinds of calcareous rocks which occur in existing coral-reefs :—

1. "*Coral-rock*," properly so called, produced by the reef-corals *growing in place*. Though essentially formed by the growing corals themselves, this rock is also largely made up of calcareous mud and the entire or broken skeletons of various lime-producing organisms other than corals, the interstices between the corals being thus completely filled up. This is more especially the case near the surface of the reef, where the branching and reticulated types of corals (such as the Madrepores) chiefly abound. "Coral-rock," produced as above, is liable to undergo secondary changes as the result of the percolation through it of water, the original coralline structure being thus more or less extensively obliterated, and the rock being converted into a compact and crystalline limestone.

2. "*Reef-rock*," produced by the action of the sea upon the reef, and consisting of fragments of broken coral mixed with the entire or broken remains of all sorts of calcareous organisms other than corals (Molluscs, Echinoderms, Foraminifera, Nullipores, &c.), the whole being cemented together by a matrix of crystalline calcite. This matrix is formed by the percolation of water through the mass, this leading to partial solution of the fragments, and to the subsequent deposition in the crystalline form of the carbonate of lime thus obtained. "Reef-rock" is always stratified, and varies in texture, according to the size of the fragments of which it is composed. Usually it is more or less compact and homogeneous; and its component organic fragments may be readily recognisable, or may

be more or less obliterated by secondary crystallisation. In some cases, where the rock is composed of large fragments of coral cemented together by calcareous *débris*, a "coral-breccia" is produced. A somewhat similar rock ("boulder-rock") is formed above the level of high water by the fragments of coral which are heaped up by the waves, and which become ultimately cemented together by the action of the spray.

3. "*Coral-mud*," formed of fine calcareous mud derived from the wear and tear of the reef by the action of the waves. Such deposits are necessarily stratified, and they are more or less fine-grained, chalk-like in appearance, and often friable. Though largely composed of minute particles of carbonate of lime, these coral-muds are often extensively made up of recognisable fragments of various calcareous organisms, or of the minute tests of *Foraminifera*.

4. "*Sand-rock*," formed above high-water mark by the action of the wind. Though subaerial in origin, the "sand-rock" is stratified; and it is composed of fine coral sand cemented together by the action of the spray of the sea, or by the percolation through it of rain-water.

Coralline limestones have been formed in all the great geological periods from the Ordovician onwards, and some of these undoubtedly represent ancient coral-reefs. In an old coral-reef we should expect to find the same two groups of calcareous rocks as have been above noted as occurring in modern reefs. We ought, namely, to meet in a fossil reef, on the one hand, with limestones formed mainly of corals which actually grew in place, and, on the other hand, with limestones produced by the contemporaneous degradation of the reef and therefore made up of the *débris* of corals and other calcareous organisms. Owing, however, to the action of denudation, it must be a matter of comparatively rare occurrence that both these groups of deposits should be found occupying their natural relative positions at the existing surface; and the rarity of such an occurrence must be in direct proportion to the antiquity of the supposed reef. In *any* case, it can only be under exceptional circumstances that the original *form* of any ancient coral-reef can have been so far conserved that it would be possible to determine that the reef was originally a "fringing reef," a "barrier," or an "atoll." In the later Tertiary rocks, no doubt, denudation may have been comparatively speaking so slight that the original form of the reef may admit of determination. Even in the Secondary rocks, however, the changes produced by displacements of the strata and subsequent denudation are so great that the original form of the reefs can hardly be more than a matter of inference. In the still more ancient Palæozoic deposits, again, the dislocations due to earth-movements have been so extensive, and the denudation subsequent to these has been so long continued and so effective, that it must always be hazardous to treat *the existing outcrops of coralline limestones as representing the original boundaries of old coral-reefs*. Hence there is a considerable element of uncertainty attaching to the so-

called "atolls" which have been described as occurring in rocks of Devonian or Carboniferous age. Not only is it theoretically improbable that an "atoll" of such high antiquity as the Devonian should have so far escaped destruction by denudation that its original *form* should still be recognisable, but these supposed atolls are found in areas which can be proved to have undergone extensive disturbance. In such cases, therefore — as, for example, in the "atolls" described by M. Dupont in the Devonian limestones of Belgium — it must be borne in mind that the observed ring-like arrangement of the limestones may well be explained as the result of denudation acting upon a series of strata which contain coralline limestones amongst their members, and which have been folded in a complex manner.

Owing to their peculiar mode of formation, it is clear that those portions of a coral-reef which are formed by corals growing in place must always be terminated by more or less abrupt boundaries; and, for the reasons above given, it is doubtful if the existing outcrops of any of the known Palæozoic limestones can be regarded as actually corresponding with the edges of old reefs. Still it may be permissible to assert that coral-reefs existed in Palæozoic time, provided the term "reef" be used in a wide sense. There are, namely, Palæozoic limestones which are more or less largely composed of corals which grew *in situ*, and these may be looked upon as constituting formations similar to existing coral-reefs, though they are mostly of small thickness, and though their present outcrops must be the result of denudation rather than of original arrangement. On the other hand, very many of the coralline limestones of the Palæozoic period have been only partially, or not at all, produced by corals growing in place, but are essentially of the nature of "reef-rock," being mainly composed of small corals, or of fragments of the larger forms, intermingled with the *débris* of innumerable calcareous organisms of other kinds, such as Crinoids, Brachiopods, Foraminifera, &c. The oldest known coralline limestones occur in the Ordovician period; but still more extensive coralline deposits are found in the Silurian. The corals of these belong principally to the Rugose and Perforate divisions of the *Madreporaria*, but there are also various forms (such as the *Heliolitidæ*) belonging to the *Alcyonaria*. Moreover, these ancient coralline limestones are largely, often preponderatingly, made up of the remains of Stromatoporoids, which are referable to the *Hydrozoa*, or of Monticuliporoids, the precise zoological place of which is not absolutely certain. In the Devonian period we meet with very extensive coralline limestones which, zoologically speaking, are closely allied to those of the Silurian, and in the formation of which the Stromatoporoids again play a very important part. The vast coralline limestones of the Carboniferous period are mostly characterised by the occurrence of Rugose corals (*Lithostrotion*, *Lonsdaleia*, *Cyathophyllum*, &c.), along with Perforate types, such as *Syringopora*; but the Stromatoporoids appear to be now wholly wanting. No true coralline limestones have hitherto been recognised in the Permian rocks; but towards the close of the Triassic period, true coral-reefs were largely developed in Western Europe. Still more extensive reefs were formed during Jurassic times in South-western and Western Europe and in Britain, and true reefs also

existed in Europe during the earlier portions of the Cretaceous period. In the earlier portion of the Tertiary period, again, vast coral-reefs were formed in Central and Southern Europe, in Egypt, Syria, and Arabia, and in parts of India. In the later portions of the Tertiary period, reefs are much more sparingly developed in Europe, but they were at this time formed on a large scale in the warmer regions of the earth's surface. In Mesozoic, Kainozoic, and recent times alike, the chief genera of reef-building corals belong to the families of the *Astræidæ*, *Poritidæ*, and *Madreporidæ*, though the *Oculinidæ* and *Fungidæ* also contribute to the formation of reefs.

With regard, finally, to the *distribution in time* of the *Actinozoa*, the *Ctenophora*, being devoid of hard parts, are unknown in the fossil condition, and need no further consideration here. On the other hand, the *Zoantharia* (including the *Rugosa*) and the *Alcyonaria* are very largely represented in past time, both sections of the class being represented by extinct types in rocks as old as the Ordovician. Speaking generally, the *Actinozoa* of the Palæozoic period belong principally to the Rugose and Aporose divisions of the *Zoantharia* and to certain abnormal groups of the *Alcyonaria*, though the Perforate Zoantharia are by no means unrepresented in rocks of this age. On the other hand, the Mesozoic and Kainozoic periods are characterised by the predominance of the Perforate and Aporose Zoantharians, these being the chief representatives of the class at the present day.

CHAPTER XVII.

CHARACTERS AND DIVISIONS OF THE ZOANTHARIA.

MADREPORARIA APOROSA.

From a palæontological point of view the order *Zoantharia* is not in a satisfactory position, since the only general definition of it which can be given is one based upon the soft parts, and therefore depending mainly upon characters which cannot be recognised in the fossil forms. The living Zoantharians *possess simple, usually numerous tentacles, and the mesenteries are never eight in number.* The mesenteries typically exhibit a more or less clearly recognisable bilateral arrangement, and usually show a hexameral symmetry; but some forms are completely radial, and the disposition of the mesenteries in hexameral cycles is often departed from. In the section of the Rugose Corals, more particularly, the symmetry is typically tetrameral. A corallum may be wholly wanting (*Actiniaria*), or a horny sclerobasis may be developed (*Antipatharia*). In most Zoantharians (*Madreporaria*) there is, however, a well-developed sclerodermic corallum, the symmetry of which varies in accordance with that of the mesenteries.

The general arrangement and structure of the soft and hard parts of the Zoantharians have been sufficiently discussed in dealing with the *Actinozoa* as a whole; but there are some points connected with the symmetry and arrangement of the mesenteries which may be briefly alluded to here:—

Hexameral symmetry obtains as a general rule, though not universally, in the *Actinidæ* (Sea-anemones), *Antipathidæ*, *Madreporaria Perforata*, *M. Fungida*, and *M. Aporosa;* the mesenteries and septa being typically arranged in cycles of six pairs each (fig. 138). On the other hand, tetrameral symmetry is commonly recognisable in the Rugose Corals, though in some of the forms generally in-

cluded in the *Rugosa* a tetrameral arrangement of the septa cannot be clearly made out.

Though showing a *general* radial symmetry, the majority of the Zoantharians at the same time exhibit a distinct bilaterality of their parts. This bilateral symmetry is shown by the presence at each end of the longitudinal gullet (fig. 138, *œ*) of a pair of mesenteries which differ in the arrangement of their muscles from the other mesenteries, and which are known as the "directive" mesenteries. In certain of the Madreporarians (*e.g.*, *Mussa*, *Euphyllia*,

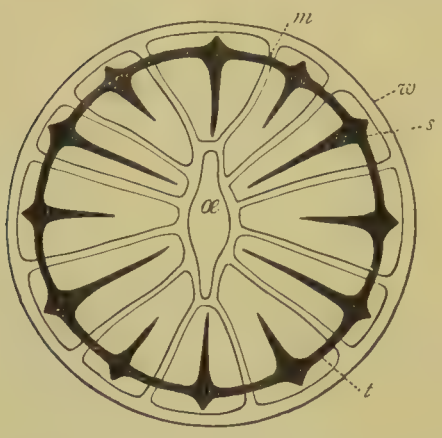


Fig. 138.—Diagram of a cross-section of *Caryophyllia*, the soft parts being unshaded and the corallum black. *œ*, Gullet, with the "directive mesenteries" (*m*) at each end; *w*, Body-wall; *s*, Septum; *t*, Theca. (Slightly altered from von Koch.)



Fig. 139.—Floor of the calice of a typical Rugose Coral (*Zaphrentis Enniskilleni*), of the natural size, showing distinct bilaterality in the disposition of the septa. *f*, The "fossula." From the Carboniferous Limestone. (Original.)

and *Lophohelia*) there are, however, no "directive mesenteries," and in such forms a *complete* radial symmetry obtains. On the other hand, in the typical Rugose Corals very distinct bilateral symmetry usually obtains, and is readily recognised by the general arrangement of the septa, or by an exaggerated or reduced development of certain of these structures. In many Rugose Corals this bilaterality is rendered specially conspicuous by the presence of a shallower or deeper groove or pit—the "fossula"—occupied by a limited number of septa of reduced size (fig. 139, *f*). Sometimes more than one fossula may be present, and the position of the pit thus named varies in different types of the Rugosa, being sometimes dorsal, sometimes ventral, and sometimes lateral.

There seems to be every ground for believing that the "fossula" of the Rugose Corals is connected with the development of the reproductive organs. On this point the observations which have been made by Moseley on the anatomy of the polypes of the recent genus *Seriatopora* are particularly instructive. It has been shown, namely, that in *Seriatopora* it is only two of the twelve mesenteries (viz., the pair of ventro-

lateral mesenteries) which develop reproductive organs. These two mesenteries are much longer than the others, and correspond to intermesenteric pouches of excessive depth, which fit into deep conical pits in the skeleton, bounded by septa of much reduced size. In accordance with these observations, it may be assumed that the "fossula" of the Rugose Corals served to lodge a special hypertrophied mesentery, or group of mesenteries, carrying reproductive organs. It is noteworthy, however, that in the recent *Seriatopora* (as also in *Madrepora Durvillei*) the two mesenteries which are modified for reproductive purposes are *on opposite sides of the polype;* whereas the fossula of the *Rugosa* is usually unilateral.

As regards the *classification* of the *Zoantharia*, the order may be divided into the three groups or sub-orders of the *Actiniaria*, *Antipatharia*, and *Madreporaria*. The first of these comprises the Sea-anemones; and, from the absence of a corallum in these forms, is sometimes spoken of under the name of *Zoantharia malacodermata*. The second group—sometimes called *Zoantharia sclerobasica*—comprises the *Antipathidæ* or "Black Corals" and their allies, in which a horny sclerobase is developed. Lastly, the great series of the Madreporarians — sometimes spoken of as the *Zoantharia sclerodermata*—comprises all the ordinary "Corals" of the present day along with the extinct group of the *Rugosa*, in all of which a well-developed sclerodermic corallum is present.

All the Zoantharians are marine, and from their common possession of a calcareous skeleton they have been largely preserved in the fossil condition. Owing to their want of hard parts, the Sea-anemones (*Actiniaria*) have left no traces of their past existence, and need, therefore, no further consideration here. The group of the *Antipatharia* also requires merely to be mentioned, as no fossil forms have been hitherto identified, the *Leiopathes vetusta* of Milne-Edwards and Haime appearing to be a Gorgonian and therefore referable to the *Alcyonaria*. There remains the great group of the *Madreporaria*, which is represented in past time by a vast series of fossil forms, and which requires, therefore, a somewhat detailed examination.

Madreporaria.

The group of the Madreporarians or *Zoantharia sclerodermata* comprises those Zoantharians in which a well-developed sclerodermic corallum, which is not simply spicular, is present. The septa of the corallum are, typically, arranged according to either a hexameral or a tetrameral system; but in some cases some other numerical law may govern the disposition of the septa, and in other cases no special symmetry may be recognisable. The organism may be simple, consisting of a single polype only, or composite, consisting of many

polypes united with one another directly, or connected by a general cœnosarc.

A strictly natural classification of the *Madreporaria* has still to be framed. By Milne-Edwards and Haime they were divided into the four sections of the *Aporosa*, *Perforata*, *Tabulata*, and *Tubulosa*; while these authorities considered the *Rugosa* as a distinct order. The section of the *Tabulata* ("Tabulate Corals") has, however, been shown to be a miscellaneous and artificial assemblage, and the types formerly included in it have now found a place in the Aporose or Perforate sections of the order, or have been relegated to the *Alcyonaria*. The section of the *Tubulosa*, again, is a small and imperfectly understood one, and the forms included in it may be temporarily placed in the *Alcyonaria*. Lastly, recent researches and discoveries have rendered hardly tenable the retention of the *Rugosa* as a separate order of *Actinozoa*; though the true affinities of many of the so-called Rugose Corals are still very uncertain. In the present state of our knowledge, the *Madreporaria* may be divided into the four primary sections of the *Aporosa*, *Rugosa*, *Fungida*, and *Perforata*. Of these, the *Fungida* do not appear to have come into existence prior to the Jurassic period; but the remaining three sections were differentiated as early as the Ordovician period.

Section I. Madreporaria Aporosa.

The division of the *Aporosa* comprises those Madreporarians in which the corallum is composed of more or less compact and solid sclerenchyma, the "theca" or wall surrounding the visceral chamber being *complete*, and not perforated by apertures or pores (fig. 140). An "epitheca" may be present. The septa are well developed, and usually have the form of solid lamellæ, though they are in some cases more or less cribriform. The interseptal loculi may be open throughout, but endothecal tissue in the form of "dissepiments" is usually more or less largely developed, while "synapticula" and "tabulæ" are sometimes present. The corallum may be simple or composite. The symmetry may be completely radial (*Mussa* and *Euphyllia*), or bilateral. The arrangement of the septa is typically hexameral, but may be tetrameral, pentameral, or otherwise abnormal.

It is difficult to speak positively as to the *geological distribution* of the *Madreporaria Aporosa*, owing to the uncertainty which attaches to the precise affinities of many fossil Corals. There are, however, various Palæozoic types which may most suitably find a place here, the Ordovician genus *Columnaria* (*Favistella*) being apparently the most ancient of these. The Silurian genus *Stauria*, in spite of its tetrameral symmetry, may likewise be regarded as an Astræid; while *Duncanella* and *Cyathaxonia*, the former Silurian and the latter Car-

boniferous, may be looked upon as early types of the *Turbinolidæ*, as, perhaps, *Petraia* and *Polycœlia* may also be. Professor Duncan further regards the Devonian genus *Battersbyia* and the Carboniferous *Heterophyllia* as representing a special group of *Aporosa* allied to the *Astræidæ*. In the Secondary and Tertiary deposits the Aporose

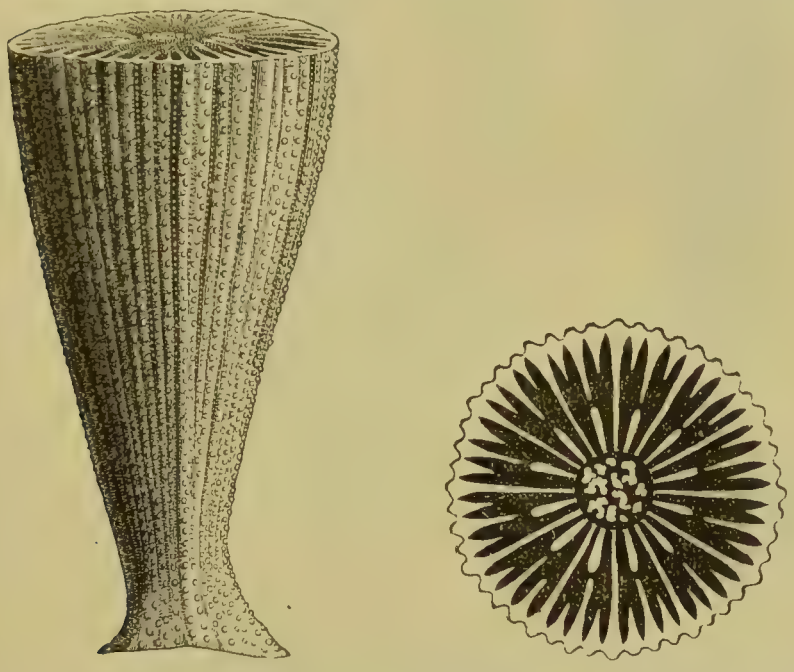


Fig. 140.—*Caryophyllia* (*Cyathina*) *Bowerbanki*, from the Gault (Cretaceous). The left-hand figure represents a specimen imperfect above, and enlarged, showing the tuberculated costæ. The right-hand figure is a magnified cross-section, showing the septa and pali. (After Milne-Edwards and Haime.)

Madreporarians are represented by a vast number of types, which do not essentially differ in plan of structure from existing forms.

The *Madreporaria Aporosa* are divided into the following families :—

Family 1. *Turbinolidæ*.—In this family the corallum is generally simple, or when compound is destitute of a cœnenchyma. The wall is solid and imperforate, and the septa are in the form of lamellæ, often granulated on their sides. The *interseptal loculi are open from top to bottom*, no endothecal structures in the form of dissepiments or synapticulæ being developed. A few Palæozoic Corals (such as *Duncanella* and *Cyathaxonia*) may be referred here, but the family is mainly Secondary and Tertiary.

The number of forms included in the *Turbinolidæ* is so large, that only a few of the leading types of the family can be here referred to in the

briefest way. In the genus *Turbinolia* itself (fig. 141), the corallum is simple and conical, with a projecting styliform columella, but without pali. The costæ are very prominent, and the spaces between them are marked with rows of small dimples, which look like perforations in the wall, but do not really penetrate to the visceral chamber. The genus is well represented in the Lower Tertiary deposits, but is doubtfully recent. In *Smilotrochus* and its allies there is no columella, and pali are rarely present. The type-genus is Cretaceous and Tertiary. The genus *Flabellum* is the type of another group of the family, and is distinguished by the compressed and wedge-shaped form of the corallum, the calice thus assuming an oval form. The structure of the wall and septa in *Flabellum* is peculiar, but is not so different from that of the same parts in certain fossil corals of other groups as to justify the removal of the genus from its present position. The species of *Flabellum* are all Tertiary and Recent. In *Placotrochus* and its allies a columella of a lamellar form is present, and there are rarely pali. The genus is Recent and Tertiary, as also is the related genus *Sphenotrochus*. The genus *Trochocyathus* is the type of an extensive series of forms, in which there is a fasciculate columella, and generally one or more cycles of pali. *Trochocyathus* itself (including *Thecocyathus*) dates from the Lias, and ranges to the present day. Allied to this is the well-known genus *Caryophyllia* (figs. 140 and 126), which ranges from the Cretaceous period to the present day, and is distinguished by its possession of a trabecular columella and a single crown of pali (fig. 128, A).



Fig. 141.—*Turbinolia sulcata*. The upper figure shows the exterior of the theca with the costæ. The lower figure shows the calice, with the columella and primary and secondary septa. Eocene.

The remaining types included in the *Turbinolidæ* are more or less abnormal. The genus *Dasmia*, for example, is so peculiar, that it has been regarded as the type of a separate family (*Pseudoturbinolidæ*), the distinctive feature being that the septa are arranged in groups of three, in such a way that each septum might be regarded as formed by the coalescence of three elements. The genus is Cretaceous and Tertiary. The Recent genera *Guynia* and *Haplophyllia*, again, are remarkable in the fact that the symmetry of the corallum is tetrameral, and they thus serve to lead us to such ancient types as the *Cyathaxoniæ* of the Carboniferous rocks. In the true *Cyathaxoniæ* (as typified by the *Cyathaxonia cornu* of the Mountain Limestone) the corallum is simple and conical, the septa having a tetrameral symmetry, and a "fossula" being present. There is a prominent columella, and the interseptal loculi appear to be free from endothecal structures. As the presence of a fossula, and the fact that the septa have a tetrameral arrangement, cannot be considered as distinctive features, there would not appear to be sufficient ground for excluding this genus from the *Aporosa*. The Silurian corals which have been included in the genus *Cyathaxonia* belong, however, to the genus *Lindstræmia*, which may also be referable to this division of the *Madreporaria*, though it will be here provisionally placed among the *Rugosa*.

Another Palæozoic type that may with great probability be included among the *Turbinolidæ*, is the Silurian genus *Duncanella*. In this genus (fig. 142) the corallum is simple and conical, with a deep calice, and a well-developed wall marked by costæ and encircling striæ. The wall, however, is deficient at the extreme base of the corallum, thus allowing the primitive septa to protude as a little cone (fig. 142, B). There are eighteen (sometimes seventeen) septa, the symmetry of which is completely radial, and which meet centrally so as to form a sort of pseudo-columella (fig. 142, C). The interseptal loculi, as in the *Turbinolidæ* generally, are completely open, and are free from endothecal structures of any kind, though the bottom of the visceral chamber is more or less extensively filled up by a deposit of stereoplasma.

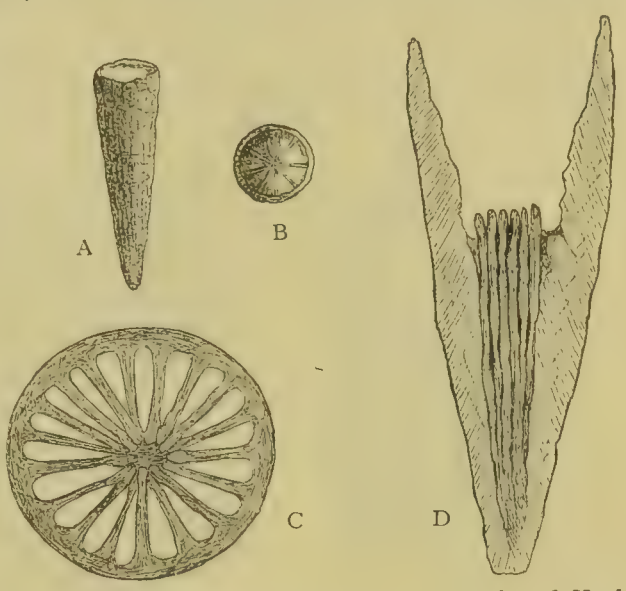


Fig. 142.—*Duncanella borealis*, from the Silurian of North America. A, Side-view of the corallum, enlarged twice; B, Base of the corallum, enlarged, showing the absence of the wall and the protrusion of the septa; C, Transverse section of the corallum, enlarged nine times; D, Vertical section of the corallum, enlarged four times. (Original.)

Lastly, it is probable that the imperfectly understood genera *Petraia* and *Polycœlia*, both of which are of Palæozoic age, may ultimately be shown to be aberrant types of the *Turbinolidæ*.

Family 2. *Oculinidæ*.—The corallum in this family is always composite (fig. 143), the new corallites being usually produced by lateral gemmation, and being united by an abundant and compact cœnenchyma, the surface of which is smooth or striated, but is not echinulate. The wall of the corallites is imperforate, not distinct from the cœnenchyma, and the lower portion of the visceral chamber usually becomes extensively filled up in process of growth by a deposition of stereoplasma. The interseptal loculi are usually open to the base, but dissepiments or (as in *Lophohelia*) tabulæ are occasionally developed.

The *Oculinidæ* appear for the first time in the Jurassic rocks (*Euhelia*, *Enallohelia*, &c.), and are also represented in the Cretaceous rocks (*Synhelia*, fig. 143, *Diblasus*, *Baryhelia*, &c.) In the Eocene Tertiary we meet with early types of the Recent genus *Oculina* itself, with its arborescent corallum and nearly smooth cœnenchyma. The well-known living genera *Amphihelia* and

Lophohelia likewise appear in the Tertiaries, the former in the Eocene and the latter in the Miocene. Lastly, the widely distributed Recent genus *Stylophora* (fig. 144) appears as early as the Eocene Tertiary. The corallum in this genus is readily recognised by its granulated cœnenchyma, the presence of a styliform columella,

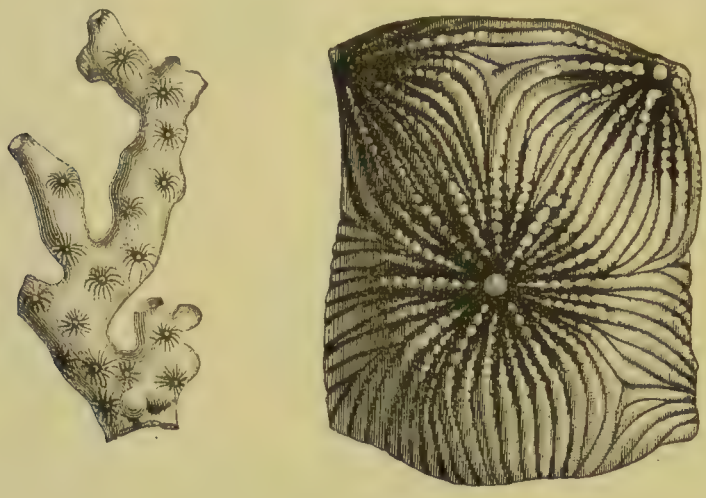


Fig. 143.—*Synhelia Sharpeana.* Cretaceous.

and the fact that there are six fully-developed septa, with an intermediate cycle of six rudimentary septa.

Family 3. *Pocilloporidæ.*—The corallum in this family is composite, with a dense cœnenchyma, the corallites having their visceral chambers largely filled up inferiorly with solid stereoplasma (fig. 145, c). The calices are oval, and are definitely oriented, their long axes corresponding with that of the branches of the corallum. The septa are small, twelve in number, with a distinct bilateral arrangement. The cavities of the polypes are placed in communication (as in the Alcyonarians) by a network of canals, which traverse the superficial region of the colony. The mesenteries of the ventro-lateral pair are, moreover, much longer than the others, and are the only ones which carry mesenterial filaments, and which develop reproductive organs. In *Seriatopora*, as shown by Moseley, these two mesen-

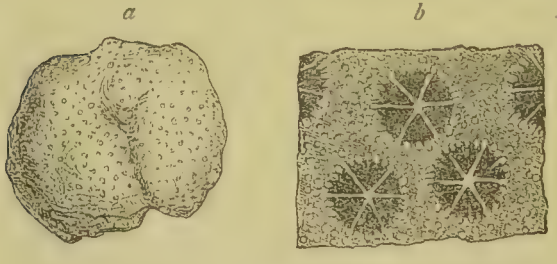


Fig. 144.—*a*, The corallum of *Stylophora subreticulata*, from the Miocene Tertiary of Austria, of the natural size; *b*, Surface of the same, enlarged. (After Zittel.)

teries correspond with especially deep intermesenteric pouches, which fit into deep pits in the floor of the visceral chamber. These pits are bounded by septa of much reduced size, and may be fairly compared with the "fossula" of the *Rugosa*.

This family comprises only the two genera *Pocillopora* and *Seriatopora*, both of which, as above shown, have certain very remarkable characters, and make a decided approach to the Rugose Corals. In *Pocillopora* (fig. 145), there is a small columella, and well-developed

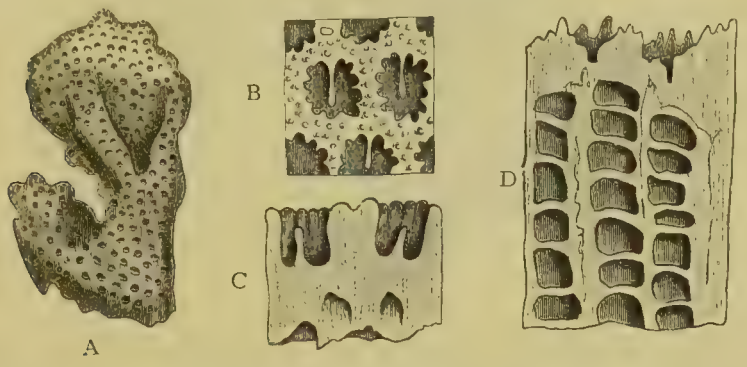


Fig. 145.—A, Portion of the corallum of *Pocillopora aspera*, var. *lata*, Verrill, of the natural size; B, Part of the surface of same, enlarged; C, Section of the corallites of the same, showing the columella, enlarged; D, Vertical section of the same, enlarged, showing tabulæ. (After Dana.)

tabulæ (fig. 145, D) are present. The genus ranges from the Miocene Tertiary. In *Seriatopora*, on the other hand, there is a large compact columella, and only traces of tabulæ are present. No fossil forms of this genus have been hitherto discovered.

Family 4. *Astræidæ*.—In this large family of the *Aporosa* the corallum may be simple or composite. Endothecal tissue in the form of dissepiments is well developed, and tabulæ are present in some forms. The septa are lamellar, their free edges being sometimes smooth or entire, sometimes dentated or ragged. The increase of the composite coralla (fig. 146) is effected by gemmation or by fission, and the new corallites usually become united directly by their walls or costæ, or in other cases by vesicular exothecal tissue, a solid cœnenchyma being rarely developed.

If *Columnaria* be admitted into the *Astræidæ*, the family is represented as early as the Ordovician period. The Silurian genera *Stauria* and *Acervularia* (as typified by *A. ananas*), the Devonian *Battersbyia*, and the Carboniferous *Heterophyllia* may likewise be regarded as Palæozoic types of the *Astræidæ*, though all depart in different respects from the ordinary forms of this family. Leaving the Palæozoic period, we find a great development of *Astræidæ* to take place towards the close of the Trias, where the

family is represented by numerous and varied types; a still further expansion takes place in the Oolites; very numerous forms are met with in the Cretaceous, and though there is some



Fig. 146.—*Thecosmilia annularis.* Coral-rag, England.

decrease in the Tertiaries, this great family still holds its ground as the most important group of the "reef-building" corals.

The family of the *Astræidæ* admits of subdivision into a number of minor groups, and comprises such a vast number of forms that it is impossible to do more here than to allude to a few of the more important types. In the first place, there is a large series of forms (*Astrææ simplices*) in which the corallum is simple and solitary. These simple Astræans appear under many generic types in the Secondary period, and have survived to the present day. Well-known genera are *Montlivaltia* (fig. 147), ranging from the Trias to the Recent period; *Trochosmilia*, ranging from the Jurassic to the Miocene; and *Parasmilia*, ranging from the Cretaceous to the present day.



Fig. 147.—*Montlivaltia caryophyllata*, showing the greatly-developed epitheca covering the lower part of the coral. Great Oolite.

In a second group of the Astræans (*Astrææ reptantes*), comprising such genera as *Rhizangia* and *Astrangia*, the corallum is composite, and consists of short corallites budded out from basal stolons or expansions. *Rhizangia* is Cretaceous and Tertiary, while *Astrangia* is represented in the Eocene Tertiary, and survives at the present day.

In a third group of Astræans (*Astrææ gemmantes*) are comprised compound forms, in which the mode of increase is "by gemmation from the wall below the calicular margin" (Martin Duncan). In this group are included various Secondary, Tertiary, and Recent corals (*Cladocora*, &c.), and Professor Martin Duncan also places here the remarkable

Palæozoic genera *Heterophyllia* and *Battersbyia*. In the former of these (fig. 148) the corallites are long and slender, increasing by budding around the calicular margin. There is a thick wall, marked by prominent costæ, which may be variously ornamented. There may be only six septa; but there is usually a larger number of these structures, their

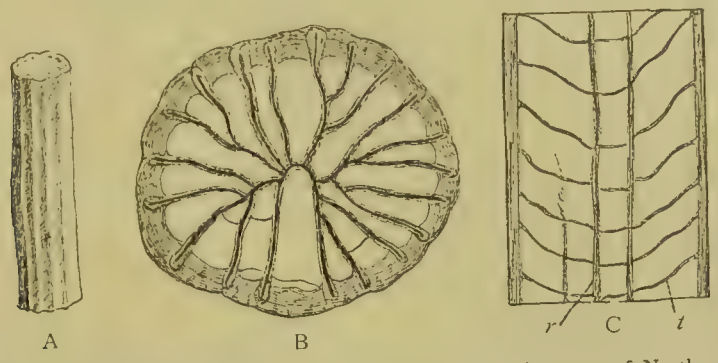


Fig. 148.—*Heterophyllia angulata*, from the Carboniferous Limestone of Northumberland. A, A fragment of the corallum, enlarged slightly. B, Transverse section of the same, enlarged seven times. C, Longitudinal section, similarly enlarged: *t* Tabulæ; *r* Cut edges of the septa. (Original.)

arrangement being distinctly bilateral, and in many respects resembling that seen in young examples of *Zaphrentis*. Some of the septa usually became coalescent, so as to give rise to fan-like groups, while the longer septa are continued to meet in the centre of the visceral chamber. There is no true columella, but a "fossula" is often present (fig. 148, B); and the septa are further peculiar in so far that the wall does not appear to

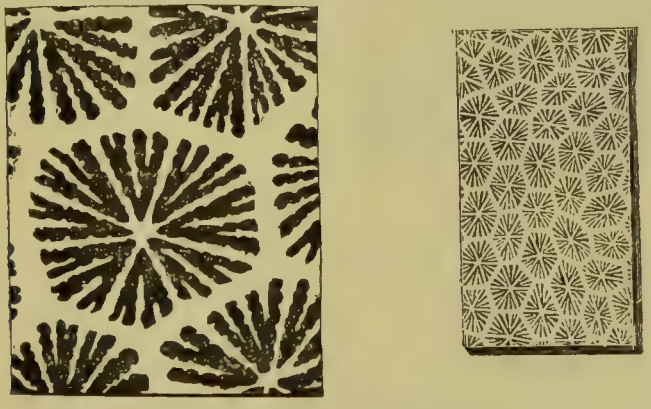


Fig. 149.—*Isastræa oblonga*; portion of a small polished slab, of the natural size, and a few calices enlarged. Jurassic (Portland Oolite).

be formed by an extension and fusion of their outer ends. Lastly, dissepiments in limited number are present, and curved "tabulæ" are well developed (fig. 148, C). The genus is only known as occurring in the Carboniferous rocks of Britain.

The genus *Battersbyia* (with which the *Fascicularia* of Dybowski may be compared) was founded to include certain Devonian corals possessing

a fasciculate corallum, composed of unequally-sized cylindrical corallites, which are not in contact laterally, or only touch each other to a limited extent. According to Professor Martin Duncan, the septa are variable in number and size, and the endothecal tissues consist of an abundance of vesicular dissepiments along with well-developed tabulæ.

In a fourth group of Astræans (*Astrææ cæspitosæ*) the corallum is more or less tufted or cæspitose, the corallites being produced by fission from a common parent, but having their terminal portions free. As examples of this large and well-marked group may be taken the recent *Mussa*, or such Secondary corals as *Thecosmilia* (fig. 146) and *Cladophyllia*, the former of these being one of the most characteristic genera of the Jurassic rocks.

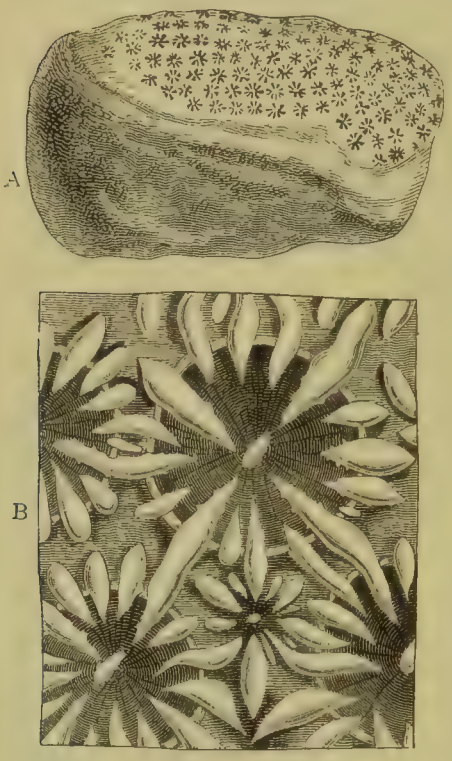


Fig. 150.—A, A small mass of *Holocystis elegans*, of the natural size; B, A few calices of the same, enlarged. Cretaceous. (After Milne-Edwards and Haime.)

In a fifth group (*Astrææ confluentes*) we have a number of well-known genera of Astræans, in which the composite corallum increases mainly by fission, this being so far imperfect that the calices of the different corallites are usually more or less completely confluent with one another. Familiar examples of this group are the genera *Diploria* (Cretaceous to Recent), *Mæandrina* (Jurassic to Recent), *Euphyllia* (Jurassic to Recent), and *Rhipidogyra* (Jurassic and Cretaceous).

All the remaining Astræans are "agglomerate" or "astræiform," consisting of numerous closely approximated corallites, which may be united by their walls directly or by cœnenchyma, and which give rise by their union to massive coralla. In certain of the forms included in this group, such as *Favia* (Jurassic to Recent), the mode of increase is essentially by fission. In others, however, including many of the most typical forms of the entire family, the mode of increase is essentially by gemmation, the new buds being usually thrown out either from the wall or from the calice of the parent. A very large number of generic types of this group are known, abounding in the Secondary and Tertiary periods, and being extensively represented at the present day. Among the more familiar genera may be mentioned *Heliastræa*, *Prionastræa*, *Isastræa* (fig. 149), *Septastræa*, *Convexastræa*, *Plesiastræa*, *Stylina*, and *Latimæandra*.

Finally, we may consider here certain forms of corals which depart more or less widely from the ordinary type of the Astræans, but which are nevertheless to be regarded as belonging to this family. The first of these is the recent genus *Merulina*, in which the corallum is composite and usually foliaceous, with a basal plate which is perforated by foramina and slits. In the possession of this perforated basal plate the genus

approaches the *Fungida*, and it has been commonly regarded as constituting a special family of the *Aporosa* (the *Pseudofungidæ*).

Another remarkable type is constituted by the genus *Holocystis* of the Lower Greensand (Cretaceous). In this genus (fig. 150) the corallum is composite, the corallites being connected directly by their walls or by costæ. There is a styliform columella, and the septa are developed in three cycles, there being four principal septa of much larger size than the others. The symmetry is thus conspicuously tetrameral, and for this reason *Holocystis* has generally been regarded as belonging to the *Rugosa*. The visceral chambers of the corallites are also intersected by tabulæ, these structures being likewise abundantly developed in the allied genus *Coccophyllum* of the Alpine Trias.

The Silurian genus *Stauria*, which has been usually referred to the *Rugosa* (*Tetracoralla*), and which has been regarded as the type of the special family of the *Stauridæ*, may also be regarded as belonging to the *Astræidæ*, since it differs from the typical Astræans in little else than its marked tetrameral symmetry. The corallum in *Stauria* (fig. 151) is

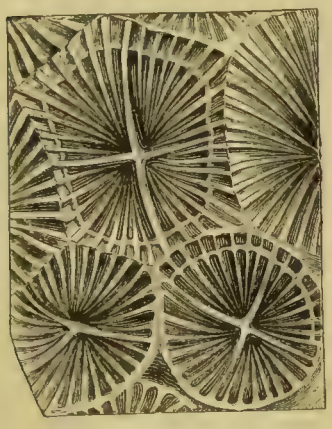


Fig. 151.—A few calices of *Stauria astræiformis*, enlarged, showing the four primary septa forming a four-branched cross. Silurian. (After Milne-Edwards and Haime.)

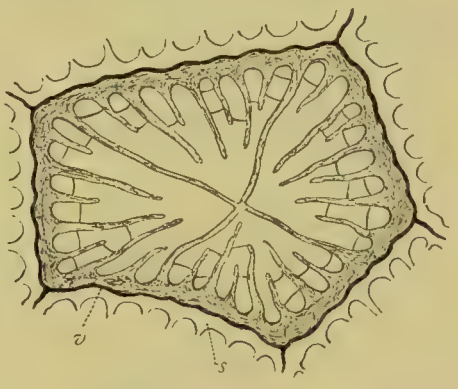


Fig. 152.—Transverse section of a single corallite of *Stauria astræiformis*, from the Silurian of Gotland, enlarged ten times. *v*, Primordial wall; *s*, Secondary layer of stereoplasma, the corresponding layer in the interior of the corallite being shaded. (Original.)

composite and astræiform, increase being effected by calicular gemmation, and the corallites being connected directly by their walls. There is no columella, but there are four principal septa which form a complete cross in each corallite (fig. 152). These four septa divide the visceral chamber into as many quadrants, each of which contains three long and four short septa. The total number of septa is thus thirty-two, sixteen long and sixteen short. The periphery of the visceral chamber is occupied by vesicular dissepimental tissue, while the central area is traversed by horizontal tabulæ. The only known species of this genus is the *Stauria astræiformis* of the Wenlock Limestone.

It would also seem not improbable that the Palæozoic genus *Acervularia*, properly so called (in so far as based upon *Acervularia ananas*, Linn., of the Wenlock Limestone of Gotland), will have to be placed among the *Astræidæ*, though this point does not admit of discussion here. On the other hand, many of the forms usually referred to *Acer-*

vularia are of a different structure to *A. ananas*, and are referable to the Cyathophylloid group of the *Rugosa*.

There does not, further, seem to be any sufficient reason for excluding the Ordovician genus *Columnaria* (= *Favistella*) from the *Astræidæ*. In this genus the corallum (fig. 153) is massive, and is composed of prismatic or polygonal corallites, which are usually more or less completely united by their walls. The septa (fig. 154, A) are well developed, and are lamellar in form, each corallite containing about thirty of these structures, disposed in two cycles, and alternately long and short. The long septa are not of equal length, one being often much longer than the others; and they fall short of the centre of the visceral chamber, no columella being present. Endothecal tissue in the form of dissepiments is very imperfectly developed, but numerous tabulæ (fig. 154, B) are present.



Fig. 153.—A colony of *Columnaria calicina*, Nich., from the Hudson River Group of Canada, of the natural size. (Original.)

Finally, the remarkable recent genus *Moseleya* must be noticed here. In this genus, as described by Mr Quelch, the corallum is

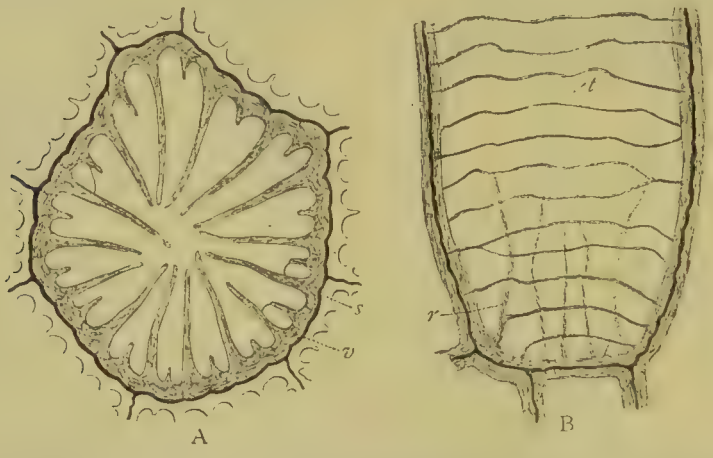


Fig. 154.—Sections of a corallite of *Columnaria calicina*, from the Ordovician of North America, enlarged ten times. A, Cross-section; B, Longitudinal section. *v*, Primordial wall; *s*, Secondary layer of stereoplasma, the corresponding layer in the interior of the corallite being shaded; *t*, Tabulæ; *r*, Cut edges of septa. (Original.)

composite, the only known specimen consisting of a single large corallite, round which smaller corallites are produced by calicinal marginal budding. The wall is very thin, with a slight epitheca; and the septa

are very numerous and are arranged in several cycles, their inner edges being dentate and giving rise superiorly to an irregular pseudo-columella. The septa are not alternately equal, and the symmetry appears to be completely radial. Endothecal tissue is largely developed, the dissepiments being vesicular in the periphery of the visceral chamber, but uniting to form distinct tabulæ centrally. In the possession of an exterior vesicular zone and the presence of a central tabulate area, the genus *Moseleya* resembles the extinct genus *Cyathophyllum ;* and it is referred by Quelch to the family *Cyathophyllidæ.* Upon the strength of this resemblance, indeed, the authority just mentioned refers the *Cyathophyllidæ*, along with the remaining corals usually grouped under the head of *Rugosa*, to the division of the *Madreporaria Aporosa.* It is possible that future researches may justify the merging of the *Rugosa* in the *Aporosa*, but it does not appear in the meanwhile that there is sufficient evidence to warrant a change so sweeping. Even as regards the genus *Cyathophyllum* itself and its immediate allies, the resemblances to *Moseleya* are not without noteworthy counterbalancing differences, as, for example, the general bilateral symmetry of the former, and the usual development of the septa in a pinnate manner along three principal lines. Still more weighty, of course, are the differences which separate the *Zaphrentoidea* and the *Cystiphylloidea* from *Moseleya.* Upon the whole, therefore, as will be more fully shown in what follows, there appears to be sufficient ground for the retention of the *Rugosa* as a special division of the *Madreporaria*, though certain of the Rugose corals of former writers may well be placed among the *Aporosa.*

CHAPTER XVIII.

ZOANTHARIA—continued.

SECTION II. MADREPORARIA RUGOSA (TETRACORALLA).

The corallum in the *Madreporaria Rugosa* may be simple or composite, and is composed of compact, solid sclerenchyma, the theca being complete and imperforate. The septa are usually well developed and lamellar, with smooth or dentated edges; but they are sometimes rudimentary. The symmetry of the corallum is almost always obviously bilateral; and the septa are generally of two orders, alternately long and short. The septa are, typically, developed according to a tetrameral system, new septa being produced along one median and two lateral lines, while a fourth line is commonly marked by a long or short septum or a fossula. A well-marked septal "fossula" is usually present, and generally corresponds with a much reduced primary septum, but there may be three or four fossulæ. Endothecal tissue in the form of dissepiments is usually largely developed; and very generally the dissepiments unite with one another in the central portion of the visceral chamber so as to form well-marked "tabulæ." The mode of increase in the composite coralla is mostly by lateral or calicular budding, and a true cœnenchyma is wanting.

It has been supposed by some naturalists that the so-called Rugose corals might possibly be referable to the *Hydrozoa*, and, at any rate, that they are not truly Madreporarian. On the other hand, Mr Quelch has recently abolished the *Rugosa* as a distinct division, and has united the corals formerly placed therein with the *Madreporaria Aporosa*. Some of the forms included in the old order of the *Rugosa* may, as previously seen, be referred without difficulty to the *Aporosa*, and as regards most of the others the view advocated by Mr Quelch can be supported by evidence of no small weight. The resemblances, namely, between the corallum of the typical *Rugosa* and that of the *Madreporaria Aporosa* are so numer-

ous and so important, that it is impossible to imagine that the coralla in the two cases were secreted by different methods, or bore dissimilar relations to the soft parts of the animals producing them. Thus, in both groups alike the simple form of corallum (fig. 155) consists of an outer wall or "theca," enclosing a central space or "visceral chamber," which is ordinarily divided into a series of compartments by vertical partitions or "septa"; in both alike the "visceral chamber" may be partitioned off into storeys by horizontal plates or "tabulæ"; in both alike the interseptal loculi are liable to be more or less subdivided by "dissepiments"; and in both alike

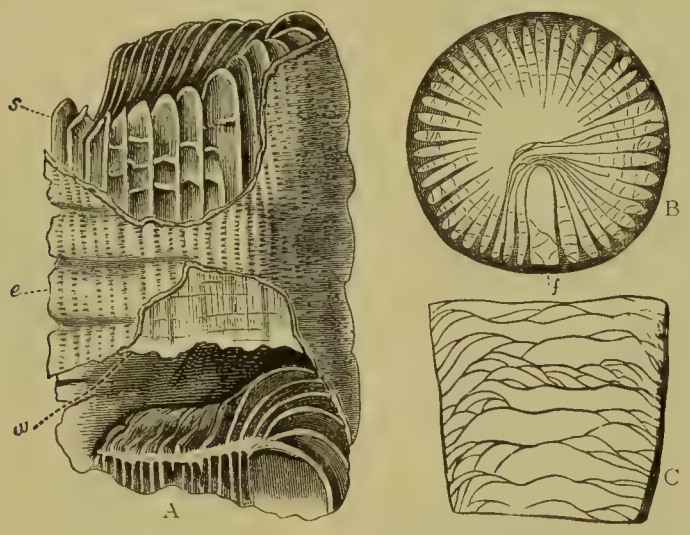


Fig. 155.—Morphology of the *Rugosa*. A, Fragment of *Zaphrentis gigantea*, showing the septa (*s*), with the sparse dissepiments crossing the interseptal loculi, the epitheca (*e*), and the thin proper wall (*w*); B, Transverse section of *Zaphrentis Guerangeri*, showing the septa and dissepiments, the central area occupied solely by the tabulæ, and the "fossula" (*f*); C, Longitudinal section of the last, showing the arrangement of the tabulæ. (A is after Edwards and Haime; B and C are after Mr James Thomson.)

the axial rod, known as the "columella," may be developed. In both groups, moreover, the corallum is often composite, and may be regarded as a variously formed aggregate of "corallites," each of these subordinate elements of the colony being essentially similar in structure to the typical simple corallum.

In spite of the above-mentioned general resemblances, it will be found, however, that the central and most typical group of the old order *Rugosa*—viz., the group of the Zaphrentoid corals—is separated from the division of the *Madreporaria Aporosa* by important morphological and developmental characters. But the Zaphrentoids are very intimately connected by many intermediate links with the *Cyathophylloidea*, the group of *Rugosa* which most nearly approaches the *Astræidæ*. The Cyathophylloids, again, have a

close connection with the typical *Cystiphylloidea*, and, through these, with the most abnormal of all the forms included in the *Rugosa* (viz., *Calceola* and its allies). Upon the whole, therefore, in the present condition of our knowledge, it seems best to retain the name *Rugosa* for the three groups of the Zaphrentoid, Cyathophylloid, and Cystiphylloid corals, and to regard these as constituting a special division of the *Madreporaria*.

While the corallum of the *Rugosa*, as above limited, is in general structure quite similar to that of the *Madreporaria Aporosa*, it possesses certain special peculiarities, which must be briefly noticed here. The structure of the *theca* or wall of the corallum in the *Rugosa* is generally in agreement with that of the *Aporosa*, the outer investment of the visceral chamber being formed by the coalescence of lateral outgrowths from the peripheral margins of the septa, as seen, for example, in *Zaphrentis* (fig. 127, c). In other cases (as in *Heliophyllum* and *Crepidophyllum*), the septa appear to end abruptly in the wall, which is very thin, and seems to be developed independently of the septa. In *Streptelasma*, again, a dense false wall is formed by the junction of the much-thickened outer ends of the septa (fig. 127, b). A true "epitheca" has been very commonly described as present in the simple Rugose Corals, but it is very difficult to demonstrate the existence of this in microscopic sections, as a structure distinct from the true wall, and it seems probable that what has been generally called the "epitheca" is in many cases really the "theca." In certain of the compound Rugose Corals, on the other hand, there exists a general epitheca enclosing the entire colony inferiorly. As regards their internal structure, the septa are usually composed, as in the *Aporosa* generally, of a median plate ("primordial septum") bounded on both sides by a layer of dense secondary sclerenchyma or "stereoplasma." In some cases, as in *Pholidophyllum*, the septa can be shown to be formed by the coalescence of obliquely directed calcareous trabeculæ, the free ends of which project at the inner margins of the septa. In *Heliophyllum* and its allies, the septa are thin, and are either unthickened by secondary stereoplasma, or have only a very thin layer of this substance on the sides of the primordial septum. In these cases the oblique trabeculæ ("Septaldornen" of the Germans) above spoken of are greatly developed, and give rise to the peculiar structures known as "carinæ," which will be more fully considered later on.

The most important features in the structure of the corallum of the *Rugosa* are, however, connected with the arrangement and mode of development of the septa. The most obvious of the peculiarities of a typical Rugose coral is the conspicuously bilateral disposition of its parts (see fig. 139). The causes of this bilaterality will be best understood by a consideration of the structure of a simple Rugose

coral, such as *Streptelasma corniculum* or *Omphyma subturbinata*. From an investigation of such types it was shown by Kunth that the symmetry of the corallum is tetrameral, and is governed by four principal septa placed at right angles to one another. The bilaterality of the corallum depends upon the mode in which new septa are developed in relation to three out of these four principal septa. The most important of the three principal septa in question is placed along the convex (or "dorsal") side of the corallum, and new septa are developed on both sides of this in a pinnate or feather-like manner (fig. 156, A). This dorsal median septum may be longer or shorter than the other septa, or of normal size, and it may be con-

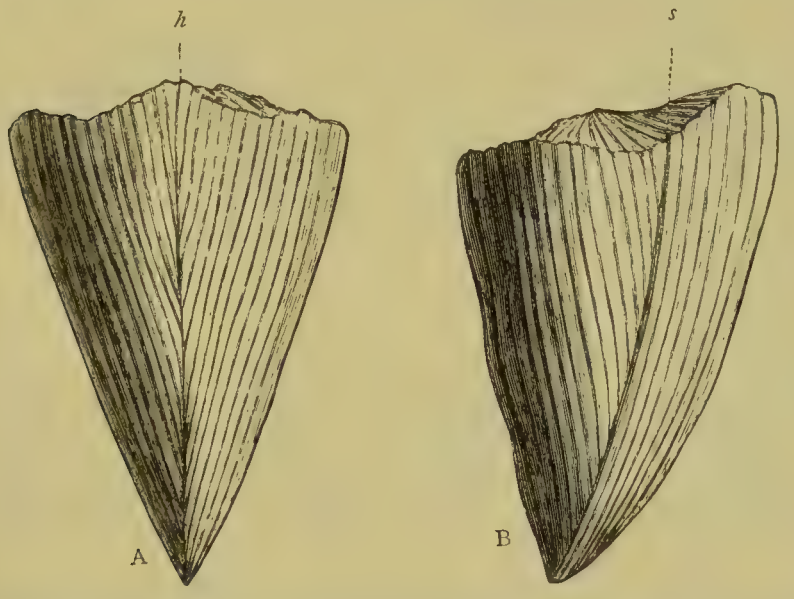


Fig. 156.—A, *Streptelasma corniculum*, viewed from its convex (or "dorsal") side, showing the intercalation of new septa on both sides of the "cardinal septum" (*h*), of the natural size. B, Side-view of the same specimen, showing the development of new septa on one side of one of the "alar" septa (*s*). From the Ordovician rocks of North America. (Original.)

veniently spoken of as the "cardinal septum" (the "Hauptseptum" of Kunth). The septa produced on the two sides of the "cardinal septum" gradually get less and less oblique to the latter, till we reach two septa placed laterally, at right angles to the "cardinal septum," which may be spoken of as the "alar" septa (the "Seitensepta" of Kunth). On the ventral side of each alar septum—*i.e.*, on the side furthest removed from the "cardinal septum"—new septa are developed in an oblique manner (fig. 156, B, *s*). The remaining septum of the quartette of principal septa is placed in the middle line on the concave (or "ventral") side of the corallum, and it does not serve as a starting-point for the development of new septa, and therefore

does not show any feather-like disposition of the septa on its sides. It may be longer or shorter than the others, and may be spoken of as the "counter" septum (the "Gegenseptum" of Kunth).

Hence, the surface of the theca of a simple Rugose coral such as *Streptelasma corniculum* is marked out by these four principal septa into as many quadrants, as shown in the annexed sketch (fig. 157) of a specimen of this coral, viewed from the base, and therefore greatly foreshortened. Thus the dorsal or convex side is divided into two "cardinal" quadrants, occupied by the pinnately developed septa which flank the "cardinal septum" (fig. 157, *h*). The two

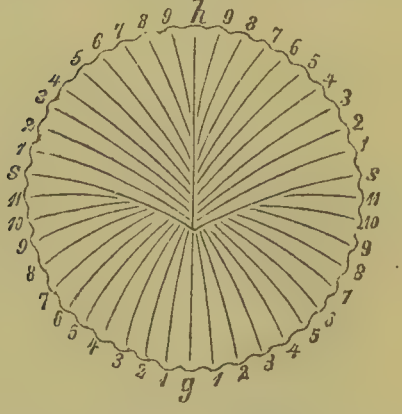


Fig. 157.—Plan of the septa in a specimen of *Streptelasma corniculum*, viewed from below, the radiating lines indicating the peripheral margins of the septa as appearing on the surface of the corallum. *h*, The "cardinal septum"; *ss*, The "alar" septa; *g*, The "counter septum." (After Kunth.)

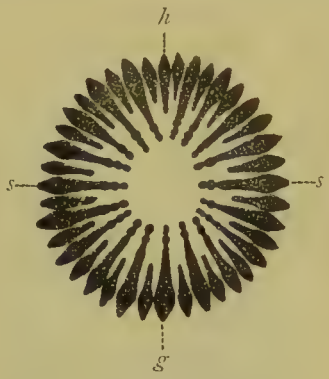


Fig. 158.—Transverse section of *Palæocyclus porpita*, from the Silurian of Gotland, enlarged three times. *h*, "Cardinal" septum, contained in the fossula; *ss*, "Alar" septa; *g*, "Counter" septum. In the section figured there are only forty septa, but there are usually forty-four, twenty-two long and twenty-two short. (Original.)

"counter" quadrants, on the other hand, are occupied by the septa developed along the ventral side of the "alar" septa (fig. 157, *ss*), and they merge with one another in the mesial ventral line, owing to the fact that the "counter septum" (*g*) is not a source for the development of new septa. It follows from the above that an inspection of the surface of a well-preserved example of *Streptelasma corniculum* or *Omphyma subturbinata* enables us to recognise by the disposition of the septa the position of the "cardinal" and "alar" septa, but that the "counter septum" cannot be thus recognised.

It was further pointed out by Kunth that though the four principal septa above spoken of divide the corallum into four quadrants, it does not necessarily follow that these contain the same number of septa each. On the contrary, it is not unusual to find that the "counter quadrants" contain conjointly a greater number of septa than do the two "cardinal quadrants."

Thus in *Palæocyclus porpita* (fig. 158), the number of septa in each quadrant is sometimes the same—namely, nine—making, with the four principal septa, a total of forty. In most examples of this coral there are, however, forty-four septa in all, the two counter-quadrants containing each eleven septa, while the cardinal quadrants have nine each.

The peculiar arrangement of the septa above indicated can be recognised in a large number of the simple Rugose corals by a mere inspection of the surface of well-preserved examples. Where the surface is badly preserved, and the observer has to rely upon thin sections, the "cardinal" and "counter" septa can usually be readily recognised, but it is often a matter of difficulty to determine the "alar" septa. In some of the most completely radial forms—as in some species of *Cyathophyllum*—the position of the four principal septa may cease to be recognisable in transverse sections of the corallum. Lastly, in cases where the septa are rudimentary—as in the Cystiphylloids generally—it may be impossible to demonstrate the tetrameral arrangement of the septa, though in other cases (as in *Goniophyllum*) no such difficulty obtains.

As regards the relative *length* of the septa, the most usual arrangement is to find that the septa are alternately equal (approximately equal, that is to say); so that the septa consist of a long series and a short series alternating with one another. Hence, the septa are often said to be of two "orders," but the septa of each order are by no means always quite equal in length, nor is it to be supposed that the septa of each order were simultaneously developed.

In a great many of the *Rugosa*, the bilaterality of the corallum is especially marked by the unequal development, as regards length, of the "cardinal" and "counter" septum, one or other of which usually occupies the so-called "fossula." The "fossula" or "fossette" (fig. 139), as previously explained (see p. 262), is a more or less conspicuous groove or depression in the calice, due to a reduction in size of the septa at that point, necessitated, in all probability, by the existence in the living polype of one or more hypertrophied mesenteries carrying the reproductive organs. As a rule, there is only one "fossula," which may be median or lateral in position, the latter being, however, very unusual. Sometimes there are three fossulæ, one median, and two lateral; while in other cases (*e.g.*, *Omphyma*) there are four of these calicine grooves, two median, and two lateral. In this last case (fig. 159, A), the four fundamental septa occupy the four fossulæ, the cardinal septum being the best developed. In the much more common case of there being only a single median fossula, this is almost always related to either the "cardinal" or the "counter" septum. The most usual arrangement is for the fossula to be placed on the convex (or "dorsal") side of the simple coralla, in which case it is intersected mesially by the "cardinal septum," which is then much *reduced in size*. This disposition of parts occurs in *Palæocyclus porpita* (fig. 158), in the genus *Streptelasma*, and in most of the species usually referred to *Zaphrentis*. Sometimes, as in *Lophophyllum*, the "cardinal" septum is very short, and occupies the dorsally-placed fossula,

while the "counter" septum is especially long. On the other hand, the fossula may be placed on the concave (or "ventral") side of the simple coralla, as in some of the species generally placed in *Zaphrentis* (*e.g.*, in *Zaphrentis Enniskilleni*, fig. 139). In this case the fossula is intersected by the "counter" septum, which is reduced in size, or may be altogether rudimentary or obsolete; while the "cardinal" septum may have its normal dimensions, or may be specially developed. In rare cases the fossula (when single) is lateral in position, and is occupied by one of the "alar" septa.

The interseptal loculi in the Rugose corals are generally more or less largely occupied by endothecal tissue in the form of dissepiments and tabulæ, both these structures being usually conjoined. The dissepiments are principally developed in the peripheral area

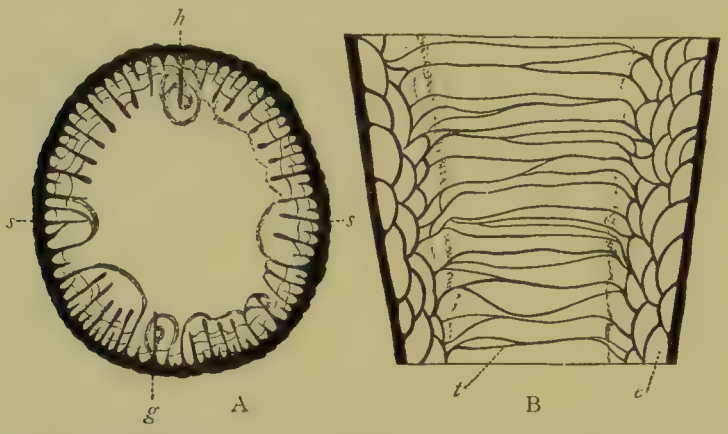


Fig. 159.—Structure of *Omphyma subturbinata*, from the Silurian of Britain. A, Transverse section, enlarged slightly, showing the four fossulæ, the arrangement of the septa, and the large central area occupied by the tabulæ: *h*, Cardinal septum; *ss*, Alar septa; *g*, Counter septum. B, Longitudinal section, slightly enlarged: *e*, Peripheral zone of vesicular dissepimental tissue; *t*, Tabulæ. (Original.)

of the visceral chamber, and have the form of curved calcareous plates directed obliquely from one septum to the next one. In transverse sections (fig. 159, A) the cut edges of the dissepiments appear as transverse lines passing directly or in a curved manner across the interseptal loculi, and connecting together adjacent septa. In longitudinal sections (fig. 159, B) the dissepiments are usually seen to give rise to an outer zone of lenticular vesicles (*e*) which are directed obliquely inwards and downwards from the internal surface of the wall towards the centre of the visceral chamber. In the central region of the corallum the dissepiments become more nearly horizontal and are developed in adjacent interseptal loculi at the same level, their coalescence giving rise to the flat or curved transverse partitions which are known as "tabulæ" (fig. 159, B, *t*). The central tabulate area of the visceral chamber varies much in extent, but is best developed in those types (such as *Amplexus*,

Omphyma, *Campophyllum*, &c.) in which the septa are short and do not extend far from the wall inwards.

The development of the peripheral zone of vesicular dissepimental tissue is also very variable, its extent being in inverse proportion to that of the central tabulate area. It is very well developed in *Cyathophyllum* and in the *Cyathophylloid* corals generally, though considerably reduced in such types as *Omphyma* and *Campophyllum*. In *Zaphrentis* and the Zaphrentoid corals in general the dissepimental vesicular zone is greatly reduced, and may be practically absent, the central tabulate area being greatly developed. On the other hand, in *Cystiphyllum* and its immediate allies the central tabulate area is invaded by the dissepiments, and the entire visceral chamber becomes filled with a vesicular tissue, the central cells of which are usually of comparatively large size, and represent tabulæ. In *Palæocyclus porpita*, and in some very flat discoid types (such as *Microcyclus*), the depth of the visceral chamber is insufficient to permit of the development of dissepiments or tabulæ. These structures are likewise obsolete in the aberrant genus *Calceola*; while they are very imperfectly developed in the genus *Lindstræmia*, owing to the fact that the lower part of the visceral chamber becomes filled by secondary stereoplasma.

As regards exothecal structures, the corallum of the Rugose corals generally exhibits externally more or less conspicuous vertical ridges, which are spoken of as "rugæ," and which are separated by intervening depressions or grooves. In some cases, these longitudinal ridges may correspond with the outer edges of the septa within, and may thus resemble the structures known in the Aporose corals as "costæ." In most cases, however, the ridges correspond with the interseptal loculi, and thus alternate with the septa. In some cases (*e.g.*, in *Pholidophyllum*) Lindström has described the vertical ridges as carrying rows of minute, overlapping, calcareous plates or scales. Other superficial exothecal structures are occasionally developed in Rugose corals, such as the surface-tubercles of some species of *Zaphrentis*, the root-like processes of attachment of *Omphyma*, &c., and the connecting-processes which unite adjacent corallites in *Eridophyllum*. The remarkable opercular plates of such genera as *Goniophyllum* and *Calceola* must also be regarded as of an exothecal nature. It must be regarded as doubtful, however, if anything which can properly be described as a "cœnenchyma" is developed in any composite Rugose coral. In such types, the corallites may remain isolated except at their point of origin from the colony; or, if in contact, they may either be united by the fusion of their walls, or the walls may be absent and the corallites are united to one another by the extension and confluence of their septa, as seen, for example, in the genus *Phillipsastræa* (fig. 160).

As regards their *classification*, the *Rugosa* are here considered as a mere section of the *Madreporaria*, instead of as a distinct order of Corals, and the signification of the name has been considerably

narrowed by the removal to the *Aporosa* of various types originally referred to this group. Thus, the Palæozoic genera *Stauria* and *Cyathaxonia*, previously generally placed among the *Rugosa*, are here relegated to the *Aporosa*, while Professor Martin Duncan has been followed in the reference to the same group of the Secondary genus *Holocystis*, the Tertiary *Conosmilia*, and the recent *Haplophyllia* and *Guynia*. As thus limited, the *Rugosa* constitute a moderately natural assemblage of forms, which may be subdivided into three main



Fig. 160.—*Phillipsastræa Verneuilli*. From the Devonian (Corniferous Limestone) of N. America. (After Billings.)

sections, which are typified respectively by the genera *Cyathophyllum*, *Zaphrentis*, and *Cystiphyllum*, and which may therefore be spoken of as the *Cyathophylloidea*, *Zaphrentoidea*, and *Cystiphylloidea*.[1] As regards their *distribution in time*, all these groups are confined, so far as at present certainly known, to the Palæozoic period, and their characters and principal types will now be briefly considered.

I. Cyathophylloidea.

The section of the *Cyathophylloidea* comprises those *Rugosa* in which the peripheral region of the visceral chamber is more or less extensively occupied by vesicular dissepimental tissue, the lenticular cells of which are directed obliquely inwards and downwards, their convex sides being turned upwards (fig. 161, B). The central area of the visceral chamber is occupied by tabulæ, but the tabulate area is often much restricted. The length of the septa is very variable, but these structures are always present and are generally alternately long and short, the septa of each order being approximately equal. In most forms there is a well-developed fossula, and the symmetry is conspicuously bilateral. In others the fossula is rudimentary or

[1] The elaborate classification of the Rugose corals put forward by Dybowski has not been adopted here, partly because many of the forms placed in this group by this observer are here removed elsewhere, and partly because the details of his proposed arrangement are largely unnatural.

obsolete, and the symmetry becomes more or less radial. A true columella may or may not be present, and the corallum may be simple or composite.

The Cyathophylloids, so far as certainly known, are confined to the Ordovician, Silurian, Devonian, and Carboniferous deposits, and are thus wholly Palæozoic.

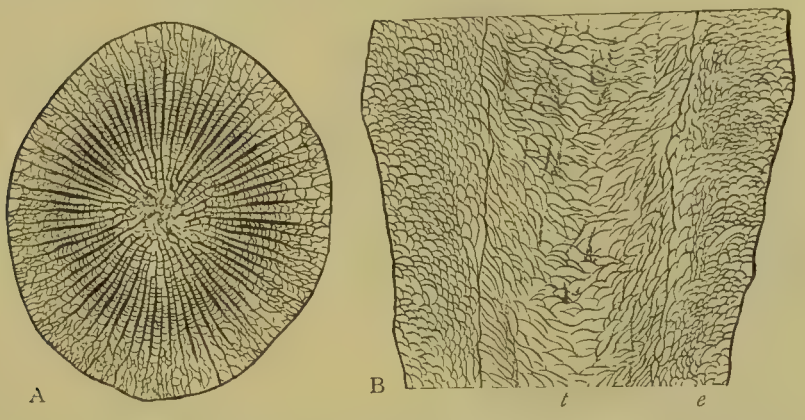


Fig. 161.—Structure of *Cyathophyllum heterophyllum*, from the Middle Devonian of Gerolstein. A, Transverse section of the corallum, slightly enlarged; B, Longitudinal section, also slightly enlarged, showing the outer vesicular zone (*e*), and the central area of anastomosing tabulæ (*t*). This is one of the species of *Cyathophyllum* in which a "fossula" is not clearly recognisable, the symmetry thus becoming completely radial. The septa nearly reach the centre, and their inner portions are considerably thickened. (Original.)

Upon the ground of a close structural resemblance between the genus *Cyathophyllum* itself and the recent genus *Moseleya*, Mr Quelch, as previously noted, has proposed the removal of all the *Cyathophyllidæ* to the Aporose Madreporarians, and the placing them in the immediate vicinity of the *Astræidæ;* but this change can hardly be accepted. It is true that there are certain species of *Cyathophyllum* which are so far similar to *Moseleya* that they show an almost complete radial symmetry, a "fossula" not being distinctly developed, while a tetrameral arrangement of the septa is not recognisable. Even within the limits of the genus *Cyathophyllum* itself, there are, however, species with a well-developed fossula and a distinctly bilateral arrangement of parts; while other allied genera are as conspicuously bilateral as is the genus *Zaphrentis*, and possess a "fossula" of precisely the same type as that of the latter. Moreover, through such genera as *Omphyma* and *Campophyllum* a complete transition is effected between the typical Cyathophylloids and the typical Zaphrentoids. Lastly, through *Cystiphyllum* it becomes easy to pass from *Cyathophyllum* or *Actinocystis* to such aberrant types as *Goniophyllum* and *Rhizophyllum*.

Family 1. *Cyathophyllidæ*.—The chief family of the Cyathophylloid corals is that of the *Cyathophyllidæ*, comprising all those members of the present section in which the septa are smooth, and consist of a median plate ("primordial septum") thickened on both sides by a layer of stereoplasma or secondary calcareous deposit.

Of the many genera of this family the three leading types are *Cyathophyllum*, *Lithostrotion*, and *Omphyma*.

In the genus *Cyathophyllum* itself, the corallum may be simple or composite, the compound forms being sometimes massive (fig. 162), sometimes fasciculate. The septa are numerous, alternately long and short, the longer ones being continued to, or nearly to, the centre of the visceral chamber, where they are usually more or less twisted, and give rise to a sort of spurious columella (fig. 161, A). The external dissepimental zone is largely developed, and is composed of oblique vesicles of small size (fig. 161, B); while the internal tabulate area is comparatively small and incompletely developed, the tabulæ having a vesicular character. The "fossula" is small or obsolete, the symmetry in the latter case becoming more or less completely radial; whereas when the fossula is recognisable, the symmetry is obviously bilateral. Many species of the genus are known, the earliest forms appearing in the Ordovician and the latest in the Carboniferous rocks. The genus is especially well represented in the Devonian and Carboniferous rocks.

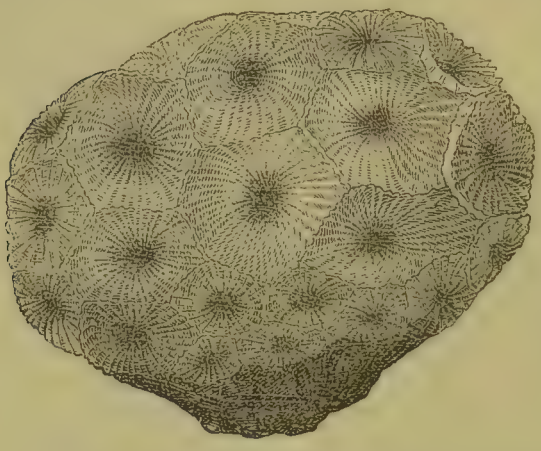


Fig. 162.—A specimen of *Cyathophyllum hexagonum*, from the Devonian Limestone of Gerolstein, of the natural size. (After Zittel.)

The Silurian and Devonian genus *Actinocystis* differs from *Cyathophyllum* proper, chiefly in the fact that the septa are imperfect, passing externally into vesicular tissue, which also largely replaces the central tabulate area. Allied genera are the *Spongophyllum* and *Endophyllum* of the Devonian rocks, in which the corallum is composite, and the septa are also more or less incomplete.



Fig 163.—*Arachnophyllum* (*Strombodes*) *pentagonum*. Silurian, Canada.



Fig. 164.—*Arachnophyllum* (*Strombodes*) *gracile*. Silurian, Canada.

The genus *Acervularia*, as based on the *A. ananas* of the Silurian

rocks, may perhaps be referred, as previously remarked, to the *Astræidæ;* but many of the astræiform corals usually placed in this genus, and especially the so-called "*Acervulariæ*" of the Devonian rocks, are nearly allied to *Cyathophyllum*. The corals in question agree in general structure, and particularly in the possession of an exterior vesicular zone, with *Cyathophyllum*, but differ from this in the fact that the central tabulate area is partitioned off and enclosed by a secondary and interior wall or "mural investment." Another type which may be placed in this neighbourhood is the Silurian genus *Arachnophyllum* (= *Strombodes*), in which the corallum is composite and astræiform (figs. 163 and 164), but the walls of the corallites, as also the septa, are very imperfectly developed, while the visceral chamber is almost filled with vesicular tissue disposed centrally in funnel-shaped layers.

As the type of another group of the *Cyathophyllidæ*, the great genus *Lithostrotion*, so characteristic of the Carboniferous deposits of many parts of the world, may be taken. The corallum in this genus (fig. 165) is always composite, sometimes massive, sometimes fasciculate, according as the prismatic or cylindrical corallites are or are not in direct contact with one another. In internal structure, *Lithostrotion* is built upon the type of *Cyathophyllum*, each corallite having an external vesicular zone and an internal tabulate area (fig. 166, B). The vesicular zone is narrow, and the tabulate area is wide, and is traversed centrally by a well-developed styliform columella. The septa are alternately long and short, their disposition being clearly tetrameral; and the symmetry is distinctly bilateral, a well-marked fossula being often recognisable. Thus, in the species here figured (fig. 166, A), there are fifty-six septa in all in each corallite, twenty-eight of these being long ones and a similar number being short. Of the twenty-eight long septa, the four leading septa are readily determined. The "cardinal septum" (*h*) is shorter than the others, and is placed in the fossula, while the "counter septum" (*g*) is placed at the opposite end of the compressed columella, a definite middle line to the corallite being thus established. At right angles to the centre of this line are the two "alar septa" (*s s*), and the remaining twenty-four long septa form four groups of six septa each, corresponding with the four quadrants of the corallite. Some of the species of *Lithostrotion* are not as regularly constructed as the above, but the same general type is preserved throughout the genus.

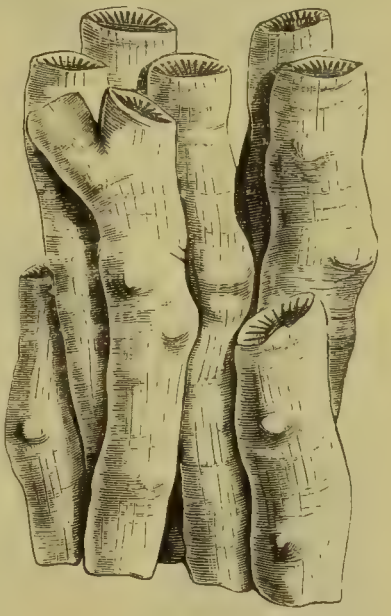


Fig. 165.—Fragment of a mass of *Lithostrotion Martini*, of the natural size. Carboniferous. (After De Koninck.)

The genus *Diphyphyllum*, ranging from the Silurian to the Carboniferous, appears to resemble *Lithostrotion* in general structure, but the corallites of the fasciculate corallum are devoid of a columella. The genus *Eridophyllum*, of the Silurian and Devonian rocks, again, seems to differ from *Diphyphyllum* principally in the fact that the long, cylin-

drical corallites are united together by horizontal connecting-processes of an exothecal nature.

Lastly, a natural transition is effected between the typical Cyathophyllids and the typical *Zaphrentidæ* by means of such genera as

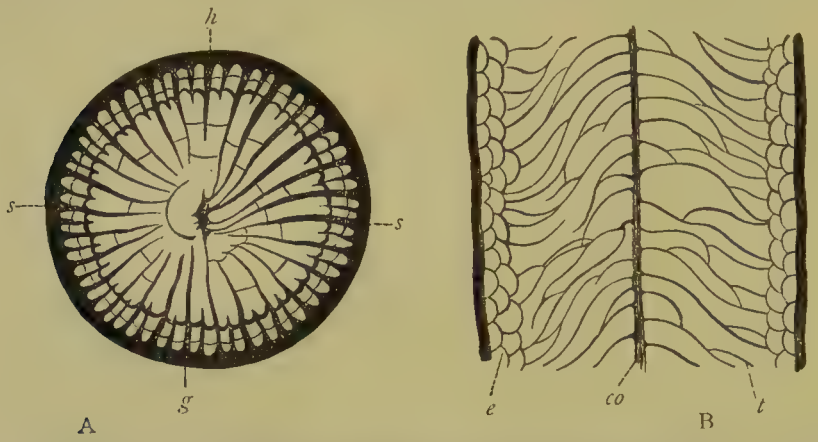


Fig. 166.—Structure of *Lithostrotion Martini*, from the Carboniferous Limestone. A, Transverse section, enlarged about 3½ times; B, Vertical section, similarly enlarged. *h*, Cardinal septum, situated in the fossula; *g*, Counter septum; *ss*, Alar septa: *co*, Columella; *e*, Vesicular tissue; *t*, Tabulæ. (Original.)

Omphyma and *Campophyllum.* The genus *Omphyma* is wholly confined to the Silurian rocks, and comprises simple, turbinate or cylindro-conical corals, the wall of which gives out root-like processes of attachment of an exothecal nature (fig. 167, *a*). The calice shows four shallow fossulæ, placed at right angles to one another, and lodging the four leading septa; and the same structure is shown in transverse sections of the corallum (fig. 159, A). The septa are numerous, and are alternately long and short; but even the longest septa extend a limited distance only into the visceral chamber, thus leaving a very extensive central area, which is occupied by the tabulæ (fig. 159, B). The genus agrees in this respect with the Zaphrentoids, but it shows its relationship with *Cyathophyllum* by the possession of an external zone of vesicular tissue, though this is comparatively of small thickness, and is

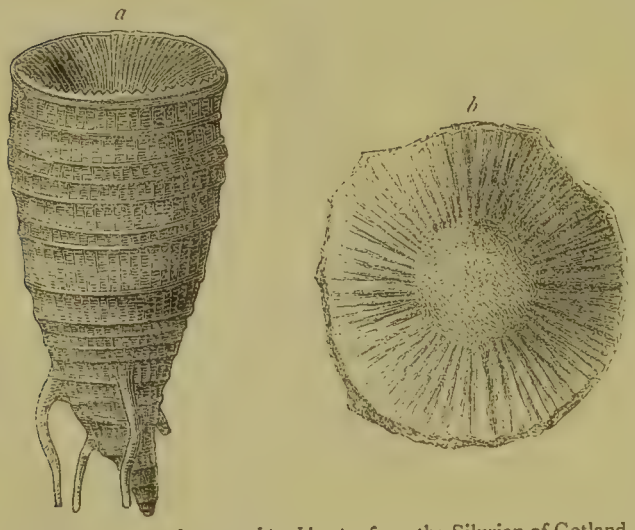


Fig. 167.—*Omphyma subturbinata*, from the Silurian of Gotland, reduced in size. *a*, Side view of the corallum: *b*, View of the calice showing the four fossulæ. (After Milne-Edwards and Haime.)

composed of comparatively large vesicles. In the reduction of the external vesicular zone and the proportionate development of the central tabulate area, the Devonian and Carboniferous genus *Campophyllum* closely resembles *Omphyma*, and also approaches the Zaphrentoids. The genus further resembles these latter, and differs from *Omphyma*, in the possession of a single very large fossula, giving rise to a conspicuous bilaterality of the corallum.

Family 2. *Heliophyllidæ*.—The members of this family agree in many respects with the typical *Cyathophyllidæ*, but are markedly distinguished from these by the characters of the septa. These structures in the present family are thin, and are composed essentially of nothing more than the primordial septal plate, occasionally with a thin coating of stereoplasma towards their bases. The septa are thickened on their sides by conspicuous lamellar ridges (representing the septal spines of such forms as *Pholidophyllum*), which are directed obliquely inwards and upwards from the exterior of the visceral chamber towards the centre of the same, and which

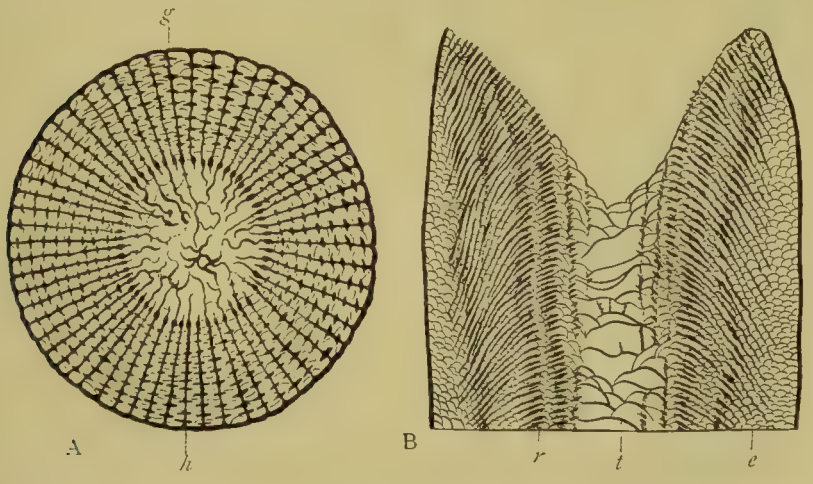


Fig. 168.—Structure of the corallum of *Heliophyllum elegantulum*, from the Devonian (Hamilton Group) of North America. A, Transverse section, enlarged nearly twice; B, Longitudinal section of the same, taken just below the calice, similarly enlarged. *h*, Cardinal septum, in the fossula; *g*, Counter septum; *e*, Peripheral vesicular zone; *t*, Central tabulate area; *r*, Oblique septal ridges ("carinal ridges") on the sides of the septa. (Original.)

form a marked feature in longitudinal sections of the corallum (fig. 168, B). In transverse sections of the corallum (fig. 168, A) these oblique septal ridges appear as conspicuous cross-bars or "carinæ,"[1] which run transversely to the septal laminæ and produce a most characteristic appearance. On the free edges of the septa, again, the septal ridges appear as prominent transverse ridges or teeth. Owing to the development of the septal ridges just spoken of, the septal

[1] The appropriate name of "carinæ" was given to these septal bars by Miss Mary E. Holmes, M.A.

laminæ often become more or less zigzag in the peripheral part of the corallum.

As regards the other characters of the *Heliophyllidæ*, the outer ends of the septa terminate with apparent abruptness in a thin outer investment, which is not improbably rather of the nature of an epitheca rather than of a true "wall.' In some cases (*Phillipsastræa*) the corallites have no definite outer investment, the septa of adjacent tubes becoming confluent. As in the *Cyathophyllidæ*, there is a well-developed external vesicular zone, and a comparatively small central tabulate area. The range of the family is from the Silurian to the Carboniferous, but the great majority of the species are Devonian, the group being, as a whole, as characteristic of the Devonian period as the family of the *Clisiophyllidæ* is of the succeeding Carboniferous period. The three leading genera are *Heliophyllum*, *Crepidophyllum*, and *Phillipsastræa*.

In the genus *Heliophyllum* itself the corallum is simple (fig. 169) or composite; the carinate septa are numerous and alternately long and short, the latter, however, being of considerable length; and the longer septa are, many of them, continued inwards to near the centre of the visceral chamber, where they become twisted, and coalesce to form a spurious columella, which is of large size, and often projects prominently into the floor of the calice (fig. 168, A). The symmetry of the corallum is distinctly bilateral, a well-marked "fossula" being present. The "cardinal septum" is shorter than the other long septa, and, along with two short septa, occupies the fossula. The exterior vesicular zone is well developed, dissepiments being exceedingly abundant, and there is a small tabulate central area (fig. 168, B). The species of the genus are principally Devonian, but some Silurian corals have also been referred here. The genus *Heliophyllum* has commonly been regarded as a mere subgenus of *Cyathophyllum*, but if due weight be given to the peculiar structure of the septa, it can hardly be placed in the family of the *Cyathophyllidæ* at all. The genus *Crepidophyllum* is in general structure essentially similar to *Heliophyllum*, but the central tabulate area is enclosed in a distinct accessory wall or inner mural investment, which is usually open on one side so as to communicate freely with the large fossula (fig. 128, B). The corallum may be simple or compound, and all the known species of the genus are found in the Devonian rocks.



Fig. 169.—A young form of *Heliophyllum Halli*, viewed from one side. Devonian. Of the natural size. (Original.)

Lastly, in the genus *Phillipsastræa* (= *Smithia*) the corallum is compound, and the internal structure of the corallites is essentially the same as in *Heliophyllum*.[1] The corallites, however, are devoid of a wall, and

[1] This statement is based on a microscopic examination of *Phillipsastræa Verneuilli*, of the American Devonian rocks, the type-species of the genus.

become united to one another by the confluence of the outer ends of the septa (fig. 160). The septa are "carinate," and alternately long and short, a distinct fossula being usually present, and the symmetry thus becoming clearly bilateral. The species of *Phillipsastræa* are principally Devonian, but the range of the genus extends into the Carboniferous period.

Family 3. *Clisiophyllidæ.*—The corals of this family agree with the *Cyathophyllidæ* and *Heliophyllidæ* in the general character of possessing a well-marked exterior vesicular zone and a central tabulate area. The central tabulate area is, however, traversed in this family by an extensively developed and complex spurious columella, formed partly of vertical, often twisted plates which have a general radial direction, and partly of vesicular tabulæ which intersect the former in an obliquely ascending direction. This massive pseudo-columella appears in the floor of the calice as a rounded or conical boss of greater or less size, the surface of which, in well-preserved specimens, shows radiating, often spiral ridges. The septa are numerous, of two sizes, alternately equal. The symmetry is usually markedly bilateral, a well-developed "fossula," lodging the "cardinal

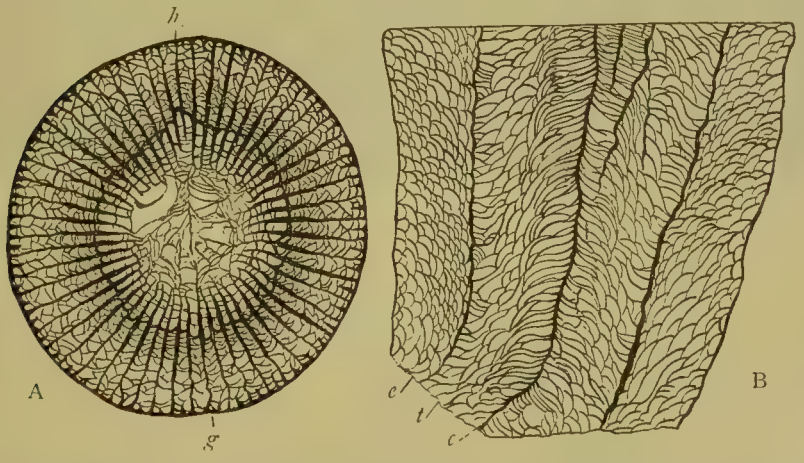


Fig. 170.—Morphology of the *Clisiophyllidæ*. A, Transverse section of *Dibunophyllum* sp., from the Carboniferous rocks of the North of England, slightly enlarged; B, Longitudinal section of the same. *h*, "Cardinal septum" situated in the "fossula"; *g*, "Counter septum"; *e*, Outer zone of vesicular dissepiments; *t*, Central area of anastomosing tabulæ; *c*, The columellar plate. (Original.)

septum," being present. The "cardinal septum" is shorter than the other long septa, and the "counter septum" is often specially developed. The septa are thickened by lateral deposits of stereoplasma, and are not "carinate." The corallum may be simple or composite. The *Clisiophyllidæ* are mainly, if not exclusively, confined to the

Milne-Edwards and Haime state that a columella is present, but no traces of this structure appear in thin sections.

Carboniferous period, the principal genera being *Clisiophyllum*, *Dibunophyllum*, *Cyclophyllum*, *Aulophyllum*, and *Lonsdaleia*.

In the genus *Clisiophyllum* the general structure of the simple corallum is as described in the above characterisation of the family *Clisiophyllidæ*. The great central pseudocolumellar mass is composed of a number of tolerably regular, radial and somewhat spiral lamellæ, which may be regarded as corresponding with prolongations of the septa, and which are intersected by obliquely directed vesicular tabulæ (fig. 171, B). As seen in the floor of the calice, the pseudocolumella forms a large rounded boss, marked by spiral radiating ridges. The zone immediately external to the pseudocolumella is occupied by inosculating tabulæ,

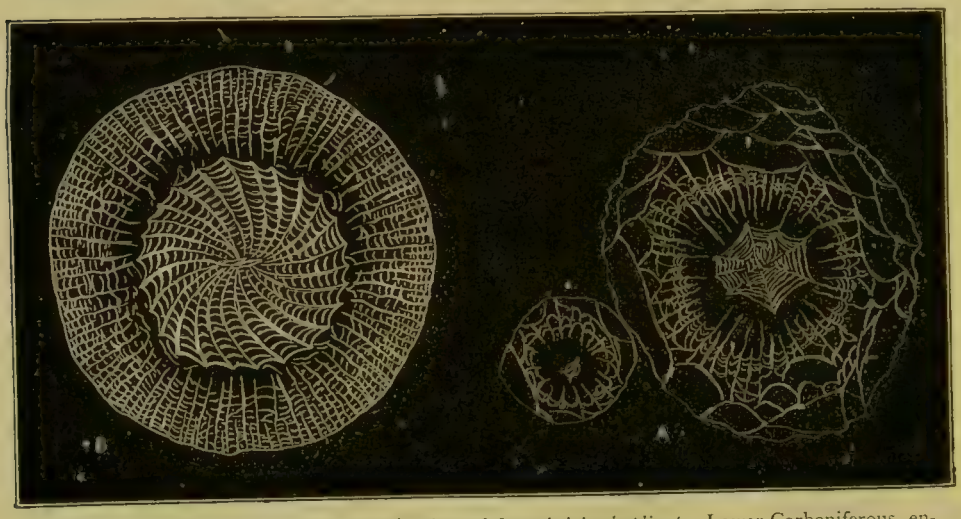


Fig. 171.—A, Cross-section of two corallites of *Lonsdaleia duplicata*, Lower Carboniferous, enlarged; B, Cross-section of the corallum of *Clisiophyllum Keyserlingi*, Lower Carboniferous, of the natural size. (After James Thomson and the Author.)

forming large vesicles; and external to this region is a deep peripheral zone of small oblique dissepimental vesicles, traversed by the septa. The septa are numerous, alternately long and short, and a well-marked septal fossula is present. The species of *Clisiophyllum* are probably wholly confined to the Carboniferous period, though some Devonian and Silurian corals have been referred here.

The Carboniferous genus *Dibunophyllum* (fig. 170) is very closely related in general structure to *Clisiophyllum*, but the pseudocolumellar area is divided into two by a vertical partition, or columellar plate, one end of which is usually connected with the "counter septum," while the other is directed to the "cardinal septum" in the fossula, the bilateral symmetry of the corallum being thus exceedingly well marked. Again, in the Carboniferous genus *Aulophyllum*, and the nearly allied or identical *Cyclophyllum*, the pseudocolumellar area is enclosed by a kind of inner mural investment or accessory wall, and is prolonged at one point into a lateral tongue-like extension directed to the fossula. The pseudocolumella has a minutely vesicular structure, the vesicles being formed by radial lamellæ intersected by obliquely ascending arched dissepiments. *Aulophyllum* stands in the same relation to *Clisiophyllum* that *Crepidophyllum* holds to *Heliophyllum*, or that the Devonian *Acervulariæ* (so-called) hold to *Cyathophyllum*.

Axophyllum, again, comprises simple Clisiophylloid corals of Carboniferous age, in which there is a large vesicular pseudocolumella piercing a central tabulate area, which is enclosed by an accessory wall, and is in turn surrounded by a vesicular zone. Lastly, we may include here the Carboniferous genus *Lonsdaleia* (fig. 134), in which there is a composite, fasciculate, or astræiform corallum. Each corallite has, as usual in this family, a large pseudocolumella, formed of twisted lamellæ, and having a vesicular structure (fig. 171, A). The columella traverses a well-developed tabulate area, but the genus differs from the other types of the family in the fact that the outer zone of the corallum is occupied wholly by large lenticular vesicles, the septa being here obsolete, and being developed in the central region only. In the series of the *Clisiophyllidæ*, *Lonsdaleia* holds the place occupied by *Lithostrotion* in the series of the *Cyathophyllidæ*.

II. Zaphrentoidea.

The section of the *Zaphrentoidea* comprises those Rugose Corals in which there is a comparatively limited amount of dissepimental endotheca, the visceral chamber never being sheathed with a zone

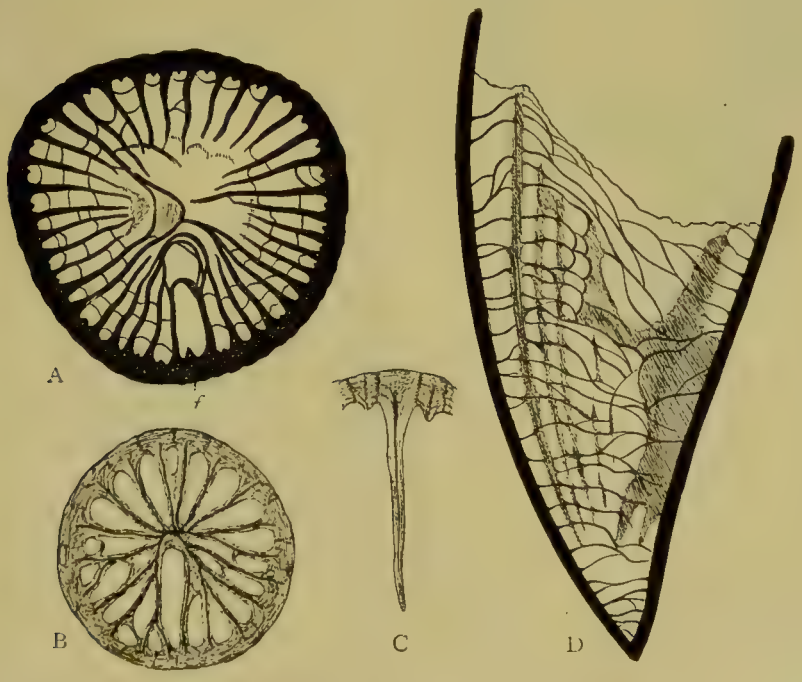


Fig. 172.—Morphology of *Zaphrentis*. A, Transverse section of a fully-grown individual of *Zaphrentis Enniskilleni*, from the Carboniferous Limestone, enlarged about twice. B, Transverse section of a very young example of the same, enlarged six times. C, Part of the theca of the same, enlarged, showing one long and two short septa, the bases of these structures forming the wall. The septa have a primordial lamina thickened by stereoplasma. D, Long section of the same, showing the tabulæ. (Original.)

of vesicular tissue; while there is, on the other hand, a proportionately extensive development of the tabulæ. [In the *Hadrophyllidæ*

and in *Palæocyclus porpita*, the corallum is so short that neither dissepiments nor tabulæ are developed at all.] The septa are thickened with stereoplasma (fig. 127, B and C), and are not "carinate." As a rule, the septa are of two orders, alternately long and short. In all the typical members of the section, the symmetry is conspicuously bilateral, and a tetrameral disposition of the septa can usually be readily determined. There is generally a well-marked fossula (fig. 172, *f*), placed dorsally and containing the "cardinal septum"; or ventral in position, enclosing the "counter septum"; or rarely lateral and traversed by one of the "alar septa." In some forms a fossula is not determinable (*e.g.*, in some species of *Streptelasma* and in *Lindstrœmia* generally). In the genera just mentioned it is also usual for the lower part of the visceral chamber to be more or less largely filled up with a deposit of stereoplasma. The Zaphrentoid Corals are exclusively Palæozoic, and range from the Ordovician to the Carboniferous period, or, if the genus *Polycœlia* be admitted here, to the Permian.

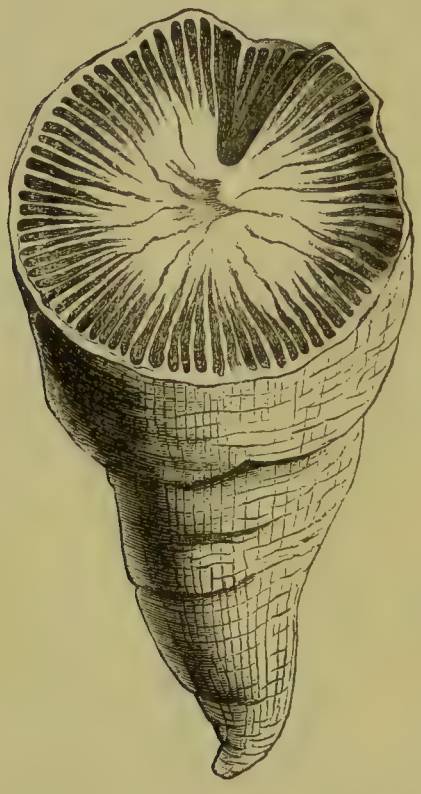


Fig. 173.—*Zaphrentis cornicula*, the walls of the calice broken away, and showing the "fossula," of the natural size. Devonian, America. (Original.)

Family 1. *Zaphrentidæ*.—The typical family of the Zaphrentoid Corals is that of the *Zaphrentidæ*, of which the genus *Zaphrentis* itself is the central form. The family is characterised by the marked bilaterality of the corallum, a well-developed fossula being present, while the development of the septa is usually characterised by the inequality in size of certain of these structures. The septum which occupies the fossula may be either the "cardinal septum" or the "counter septum," but in either case it is shorter than the other long septa. Neither a true columella nor a pseudocolumella are developed, and there is a thick theca formed by the coalescence of outgrowths from the outer ends of the septa (fig. 172, C). It is doubtful if a true epitheca is present.

Only the more important of the genera of the *Zaphrentidæ* can be here noticed, the chief being *Zaphrentis* itself. In this genus (fig. 173) the

corallum is simple, conical, turbinate, or cylindrical in form, more or less curved, and showing a conspicuous fossula in the obliquely placed calice. The fossula in different species is on the convex side of the corallum ("dorsal"), or on the concave side ("ventral"), or in rare cases is lateral. The septum included therein is usually very short (fig. 172, A and B), and may be obsolete, while more or fewer of the septa on each side generally bend round, and, partly coalescing, enclose the wide inner end of the fossular groove. The septa are moderately numerous, alternately long and short, the latter being commonly rudimentary and sometimes partly obsolete. The long septa extend a considerable distance inwards towards the centre of the visceral chamber, and often show a tendency to coalesce in groups. Dissepiments are sparingly developed in the outer zone of the corallum, but tabulæ are largely developed, and pass from side to side of the visceral chamber (fig. 172, D), often becoming united to form large arched vesicles. The species of *Zaphrentis* are mainly Carboniferous and Devonian, but some forms referred to the genus are Silurian.

The Devonian and Carboniferous genus *Amplexus* is closely similar to *Zaphrentis*, but the simple corallum is usually cylindrical in form, while the septa are much less perfectly developed, being confined to the margin of the visceral chamber, and thus leaving exposed a large central space occupied by nearly horizontal, complete tabulæ.

In the Carboniferous genus *Lophophyllum* there is a simple conical corallum of small size (fig. 174), which agrees with *Zaphrentis* in the scanty development of dissepiments and the possession of complete arched tabulæ. There is also a small fossula, which lodges the "cardinal septum" (fig. 174, B, *h*), this being shorter than the other septa. On the

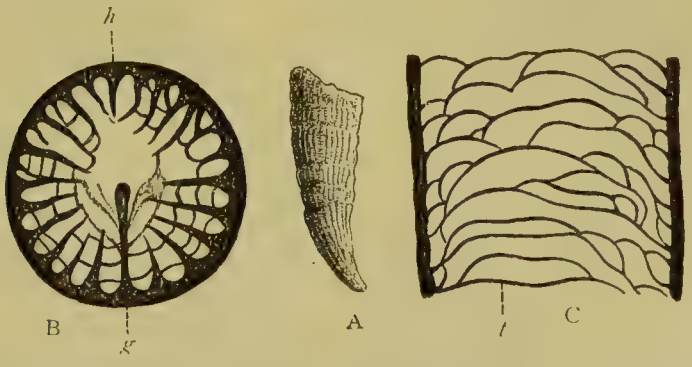


Fig. 174.—Structure of *Lophophyllum eruca*, from the Carboniferous Limestone, Scotland. A, Side-view of the corallum, enlarged slightly; B, Transverse section of the same, enlarged four times; C, Longitudinal section of the same, similarly enlarged. *h*, Cardinal septum; *g*, Counter septum; *t*, Tabulæ. (Original.)

other hand, the "counter septum" (fig. 172, B, *g*) is greatly developed, being much longer than the other septa, and having its inner extremity swollen. This enlarged septum has been regarded as a true columella, but an examination of very young specimens shows that its real nature is as just described. The remaining septa are unequal in size, but a division into alternately long and short septa cannot be recognised.

In the Carboniferous genus *Menophyllum*, again, there are three fossulæ, the largest being on the dorsal side of the corallum, and lodging the "cardinal septum," while the other two are lateral and lodge the

"alar septa," the tabulate area in the floor of the calice thus assuming the form of a half-moon. Lastly, in the Devonian genus *Anisophyllum* (fig. 175), the cardinal and alar septa are specially developed, and form three prominent ridges in the cup of the calice.

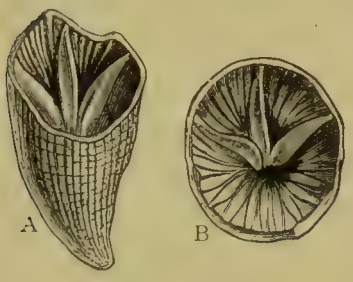


Fig. 175.—A, *Anisophyllum Agassizi*, slightly enlarged; B, Calice of the same, viewed from above—Devonian. (After Milne-Edwards and Haime.)

Outside of the typical family of the *Zaphrentidæ* are various Zaphrentoid corals which in the present state of our knowledge can only provisionally be arranged in groups, and the true affinities of which are not always clear. One group of forms, which may be provisionally spoken of as that of the *Hadrophyllidæ*, comprises certain singular little discoid corals for which the genera *Hadrophyllum*, *Baryphyllum*, *Combophyllum*, and *Microcyclus* (fig. 176) have been founded. In these singular types the simple corallum has the form of a flattened disc, the calice being so shallow as hardly to deserve the name, while the base is also often flat, the corallum thus becoming coin-shaped. There is generally a marked septal fossula, and the symmetry is conspicuously bilateral. The septa are smooth-edged, and irregular in



Fig. 176.—*Microcyclus discus*, from the Devonian (Hamilton Group) of North America. A, Upper surface of the corallum; B, Under surface of the same. The cross shows the natural size of the corallum. (Original.)

length, and the interseptal loculi are filled up with stereoplasma, no dissepiments nor tabulæ being developed. All the types of this group, so far as is certainly known, are found in rocks of Devonian age.

The type of a second group (*Palæocyclidæ*) is constituted by the singular *Palæocyclus porpita* (fig. 177) of the Silurian rocks of Gotland.[1] The corallum in this form is discoidal, the flat circular base being covered with a concentrically striated basal plate. The septa are forty-four, or rarely forty, in number, alternately long and short, the "cardinal septum" being shorter than the other septa, and being placed in a well-marked "fossula" (figs. 158, and 177, A), the symmetry thus becoming bilateral. The "counter septum" is not specially developed. All the septa are tuberculated and have crenulated edges. There are no dissepiments nor tabulæ, but the interseptal loculi are not filled up with stereoplasma. In this respect, as also in the crenulated form and more regular develop-

[1] *Palæocyclus porpita* certainly occurs also in the Wenlock Limestone of Britain (Dudley), but the *P. Fletcheri* of the same formation does not appear to be properly referable to the genus *Palæocyclus*, but belongs to *Pholidophyllum*.

ment of the septa, *Palæocyclus porpita* differs from the group of which *Hadrophyllum* is the type. The affinities of *Palæocyclus* cannot be regarded as clearly established. It is possible that the genus, instead of being placed here, should be looked upon as holding the same



Fig. 177.—*Palæocyclus porpita*, from the Wenlock Limestone of Gotland. A, Upper surface (calice) of the corallum, showing the cardinal septum in the fossula (*h*); B, Side-view of the corallum; C, View of the flat under side of the corallum, with the concentrically striated epitheca. All the figures are enlarged about twice. (Original.)

position to the *Heliophyllidæ* that *Hadrophyllum* and its allies do to the *Zaphrentidæ*.

The genus *Streptelasma* may be regarded as the type of another group of Zaphrentoid Corals, to which the name *Streptelasmidæ* may be given. The corallum in this genus is simple and turbinate or conical in form. A true "theca" does not seem to be present, but the septa become much



Fig. 178.—Structure of *Streptelasma corniculum*, from the Ordovician rocks (Cincinnati Group) of North America. A, Transverse section; B, Longitudinal section of the corallum, enlarged twice. The transverse section shows the thick false wall formed by the fusion of the outer portions of the septa. *h*, Cardinal septum situated in the fossula; *g*, Counter septum. In the specimen figured there are one hundred and eight septa, alternately long and short. (Original.)

thickened towards their outer edges, being fused with one another by their lateral margins for a considerable distance, and thus giving rise to a dense false wall (figs. 127, B and 178, A). The septa are numerous, of two orders, alternately long and short, the latter being buried for the greater portion of their length in the false wall. The symmetry is distinctly bi-

lateral, the cardinal and alar septa being clearly recognisable, in well-preserved specimens, by the pinnate arrangement of the costal furrows on the exterior of the corallum (fig. 156). The cardinal septum is reduced in size, and usually occupies the centre of a large fossula (fig. 178, A), but in some species (*e.g.*, in *S. europæum*) a fossula is wanting. The lower part of the visceral chamber is more or less extensively filled up with stereoplasma, and the upper part of the same is crossed by irregular tabulæ, dissepiments being also developed in moderate numbers. The centre of the visceral chamber is occupied by a large, irregularly reticulated or trabecular pseudocolumella (fig. 178, A), with which the inner ends of the long septa are directly connected, and which is highly characteristic of the genus. The species of *Streptelasma* are mainly Ordovician, but Silurian forms have also been recorded. The genus *Ptychophyllum* (if judged by the structure of the mushroom-shaped *P. patellatum* of the Silurian rocks) is very closely related to *Streptelasma*, the principal difference being that in this case the pseudocolumella is produced by a twisting together of the thickened inner ends of the longer septa. If, as maintained by Lindström, these two genera are to be regarded as identical, the name of *Ptychophyllum* will have to be suppressed in favour of the older title of *Streptelasma*.

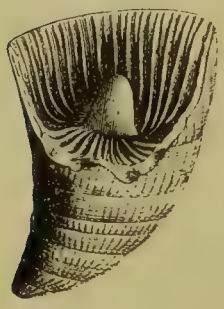


Fig. 179.—*Lindstræmia Dalmani*. A portion of top of the theca is broken, in order to show the interior of the calice. Silurian.

Lastly, we may possibly place among the *Zaphrentoidea* the small, simple Palæozoic corals which constitute the genus *Lindstræmia* (fig. 179). These forms agree with the typical *Rugosa* in the pinnate arrangement of the septa and the resulting bilateral symmetry of the corallum, but they do not appear to possess a fossula. The distinctive feature in the genus is the fusion of the septa by their inner ends to form a sort of pseudocolumella, which is often of great size and projects into the floor of the calice. The lower portion of the visceral chamber is more or less extensively filled up by stereoplasma, but dissepiments and tabulæ are scantily developed in its upper portion. The species of *Lindstræmia* are mostly Ordovician and Silurian, but the genus survives into the Carboniferous period.

III. Cystiphylloidea.

The section of the *Cystiphylloidea* comprises those Rugose Corals in which endothecal tissue in the form of dissepiments is in general extensively developed, while tabulæ are absent or are incompletely developed, and the septa are more or less imperfect, and may be reduced to mere marginal striæ. When the septa are so far developed as to enable this point to be determined, it can be shown that the symmetry of the corallum is distinctly bilateral, and in some cases a well-marked fossula is present. The Cystiphylloid corals are wholly Palæozoic, and are confined to the Silurian and Devonian rocks.

Family 1. *Cystiphyllidæ*.—This is the typical family of the Cysti-

phylloid corals, and is characterised by the fact that the endothecal structures are more or less completely reduced to a vesicular tissue, composed of lenticular cells, which are often of specially large size in the centre of the visceral chamber, and in this region represent

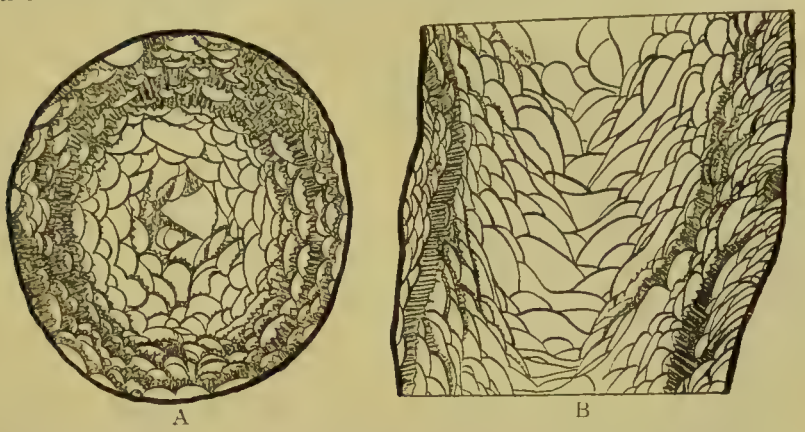


Fig. 180.—Structure of *Cystiphyllum cylindricum*, Lonsd., from the Wenlock Limestone of Ironbridge. A, Transverse section, enlarged twice; B, Part of a vertical section, similarly enlarged. (Original.)

tabulæ (fig. 180). The septa are rudimentary, but are usually recognisable as more or less distinct striæ or ridges on the surface of the calice.

The type-genus of this family is *Cystiphyllum* itself, in which the corallum is almost invariably simple (it is composite in the *C. fruticosum* of the American Devonian rocks), and is usually conical in form (fig. 181), though in some cases greatly flattened. The wall is well developed, and the visceral chamber is entirely filled with a vesicular tissue of obliquely disposed lenticular cells, which in the central region of the corallum often show a well-marked arrangement in funnel-shaped layers. The calice sometimes exhibits nothing but the rounded upper surfaces of the lenticular vesicles just spoken of, but its surface commonly shows more or less marked radial ridges or radiating rows of tubercles, which represent the septa. In some cases, as in the Devonian *C. sulcatum* and *C. lamellosum*, a well-marked dorsal fossula is present; and in the latter species it is sometimes even possible to recognise a disposition of the septal ridges in four groups, corresponding with the four quadrants of a typical Rugose Coral. All the known species of *Cystiphyllum* are found in the Silurian or Devonian rocks, one of the commonest species being the *C. vesiculosum* (fig. 181) of the Devonian rocks of North America and Europe. Through *Actinocystis* a transition can without violence be effected between the genus *Cystiphyllum* on the one hand and *Cyathophyllum* on the other hand.

Family 2. *Calceolidæ*. — This family has been founded for a number of remarkable Palæozoic corals, of which the principal genera are *Goniophyllum*, *Rhizophyllum*, *Aræopoma*, and *Calceola*. The corallum in this family is simple and conical in form, very

commonly more or less angulated, and assuming a pyramidal or quadrilateral figure. Internally, the structure may not differ essentially from that of *Cystiphyllum*, the visceral chamber being filled with an endothecal vesicular tissue, and the septa being incomplete or rudimentary (fig. 182, B). Sometimes the septa are obsolete, but they are usually recognisable as radiating ridges or rows of tubercles in the calice, or they may even form radiating lamellæ which intersect the marginal region of the visceral chamber. The essential character of the family, however, is found in the fact that the calice is closed by a variously constructed lid or "operculum," composed of one or more pieces (fig. 182, A). In this feature, the corals of the present family differ from all recent Madreporarians, though a species of operculum is found in some living Alcyonarians (*Primnoa* and *Paramuricea*). The structure and affinities of the family of the Operculate Corals have been admirably worked out by Lindström; and all the known genera of the family are Silurian or Devonian.

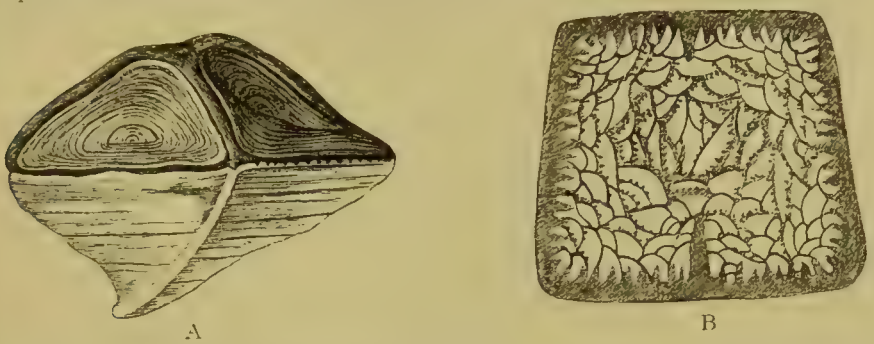


Fig. 181.—*Cystiphyllum vesiculosum*, showing "rejuvenescence," the corallum consisting of a succession of cups produced by budding from the original polype. One side of the calice is broken away, and shows the internal structure. Of the natural size. Devonian, America and Europe. (Original.)

In the Silurian *Goniophyllum* (fig. 182) the corallum is distinctly quadrilateral, its four sides being flattened. The internal structure is wholly vesicular, the cells of the central region of the visceral chamber being of large size and representing tabulæ. The quadrangular calice is deep, and is furnished with marked septal ridges, of which four—one in the middle of each side—are specially prominent, the longest being the "cardinal septum," while the other three are the "counter" and "alar" septa. The septa are not mere calicine striæ, but are truly lamellar, though they are marginal. The calice is closed with

an operculum of four calcareous plates, of which the dorsal and ventral ones are trapezoidal and the lateral ones are triangular.

In *Rhizophyllum* the conical or pyramidal corallum is attached to foreign objects by root-like exothecal processes developed from its flattened under surface, the upper surface being rounded. The calice has septal striæ and a distinct fossula, the internal structure is wholly of



A B

Fig. 182.—A, *Goniophyllum pyramidale*, from the Silurian of Gotland, showing the operculum in place, twice the natural size; B, Transverse section of the same species, slightly enlarged. (A is after Lindström; B is original.)

oblique vesicles, and the operculum is in the form of a single semicircular plate. The species of the genus are mostly Silurian, but one form is found in the Lower Devonian.

Still more closely allied to *Cystiphyllum* is the genus *Aræopoma*, comprising only the *A.* (*Cystiphyllum*) *prismaticum* of the Silurian rocks. The corallum in this form is subangular, more or less clearly four-sided, the calice having radial rows of septal tubercles, and the surface exhibiting distinct rugæ. Internally the structure is wholly vesicular, and the calice is closed by an operculum of subtriangular valves.

Lastly, in the genus *Calceola* (fig. 183), the slipper-shaped corallum is free, and has the form of a slightly curved four-sided pyramid, of which one side is broad and flat, the opposite side being equally broad but convex, while the lateral faces are much reduced, and are only represented by the rounded junctions of the two broad faces. The calice is deep, corresponding in form to the exterior, and marked internally with distinct septal striæ. The "cardinal septum" is clearly marked, and is placed in the centre of the vaulted side of the corallum, sometimes in a distinct groove or fossula, while the septa on both sides of this have a pinnate arrangement. The "counter septum" is in the middle of the flat side of the corallum, and is also often in a distinct fossula. The calice is closed by a half-moon-shaped operculum, which resembles the valve of a Brachiopod in form and sculpturing, its under surface, however, showing a prominent median and fainter lateral septal ridges. The internal structure is dense, the thick wall apparently solid, but showing, according to the observations of Kunth, a finely vesicular structure. The only known species of this genus is the *Calceola sandalina* of the Middle Devonian rocks, an abundant and characteristic fossil in



Fig. 183.—The corallum of *Calceola sandalina* (a small example), from the Middle Devonian of Gerolstein, viewed from its rounded side, of the natural size.

strata of this age in Europe. It may be noted in connection with *Calceola sandalina* that the internal structure of the curious *Cystiphyllum lamellosum* of the same geological horizon exhibits, in its young stages, a curious resemblance to that of the present form, the latter, however, not being known to possess an operculum. This fact, along with the general identity in structure between *Aræopoma prismaticum* and the typical *Cystiphylla*, may be taken as fully corroborating Lindström's conclusion that these remarkable Operculate Corals cannot be separated from the *Madreporaria Rugosa*.

CHAPTER XIX.

ZOANTHARIA—continued.

MADREPORARIA FUNGIDA AND PERFORATA.

SECTION III. MADREPORARIA FUNGIDA.

This section includes simple or composite Madreporarians, in which the interseptal loculi are crossed by trellis-like calcareous bars ("synapticula"). In the composite forms, where adjacent corallites are connected by prolongations of their septa ("septo-costæ"), the interspaces between these prolongations are also synapticulate. The septa are lamellar, and are usually solid, though occasionally perforations exist. When there is a basal plate it is usually perforated by apertures, but it may be imperforate. Endothecal structures (dissepiments and columella) may or may not be developed. Tentacles in the living forms "short, lobe-like, scattered, sometimes obsolete" (Duncan).

So far as certainly known, the section of the *Madreporaria Fungida* has no Palæozoic representatives; but the Secondary and Tertiary deposits have yielded a large number of fossil forms, only a few of the more important of which can be alluded to here.

By Professor Martin Duncan the section of the *Fungida* is divided into the following five families:—

Family 1. *Plesiofungidæ.*—This family is related to the *Aporosa*, and comprises simple or composite *Fungida*, in which dissepiments exist in addition to the synapticula, and the septa are usually solid and imperforate. The principal genus in this family is *Thamnastræa*, including a large number of species, which range from the Trias to the Miocene Tertiary, and have a very wide geographical distribution. In this genus the corallum is composite and is usually massive or lobate in form, sometimes laminar or encrusting; while the corallites have ill-defined walls. The calices (fig. 184, A) have distinct centres, but are shallow, and the septa become con-

fluent with those of neighbouring cups by means of septo-costal prolongations. The septa appear to be sometimes perforated, sometimes imperforate (Duncan), and both dissepiments and synapticula are developed, a variably shaped columella being also

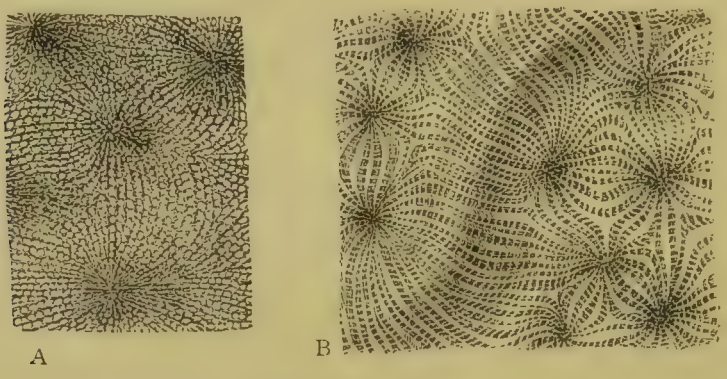


Fig. 184.—A, Surface of *Thamnastræa agaricites*, from the Cretaceous deposits of Gosau; B, Surface of *Comoseris conferta*, from the Oligocene Tertiary of Vicenza, enlarged twice. (After Zittel.)

present. Closely allied to *Thamnastræa* is the Jurassic genus *Clausastræa*.

Family 2. *Fungidæ*.—In the true *Fungidæ* the corallum is simple or compound, the interseptal loculi showing numerous synapticula, but there being no dissepiments. The septa are usually imperforate, and the basal wall is generally perforated. As restricted by Duncan, this family comprises no other fossil genus than the *Micrabacia* of the Cretaceous rocks. In this genus the corallum is of small size, free and unattached, of lenticular form, with a convex base covered with a perforated basal plate.

Family 3. *Lophoseridæ*.—In this family the corallum may be simple or compound, the wall being imperforate, and the septa also usually solid. There are synapticula, but no dissepiments. The simple forms of this family may be turbinate, discoid, or attached by a wide base, and are represented in Secondary and Tertiary deposits by various generic types (*Trochoseris*, *Cycloseris*, *Podoseris*, &c.) The composite types have their calices united by confluence of the septo-costæ, and usually possess a thin laminar or frond-like corallum. Besides such recent genera as *Lophoseris* and *Mycedium*, we have here a number of fossil types, some of which (such as *Protoseris* and *Comoseris*, fig. 184, B) are found in rocks as ancient as the Jurassic.

Family 4. *Anabacidæ*.—This small family includes only the two genera *Anabacia* and *Genabacia*, the former being simple and the latter composite, and both being confined to the Jurassic rocks. The septa in these genera are perforated, and the wall is indistinct,

while there are synapticula but no dissepiments. *Anabacia* is discoid in form, and of small size, and its basal wall is wanting.

Family 5. *Plesioporitidæ*.—This family includes *Fungida* in which the septa are trabeculate and the septa regularly porous, thus approaching the *Madreporaria Perforata*. When a wall is present, it is imperforate. Synapticula are present, and dissepiments may or may not exist. Most of the genera included in this family (*Leptophyllia*, *Cyclolites*, *Microsolena*, &c.) are Jurassic or Cretaceous, the well-known genus *Cyclolites* occurring in both of these formations. In this genus (fig. 185), the corallum is simple and free, discoid, with a flat or slightly concave base, and either circular or elliptical in outline. The under surface of the corallum is covered with a well-developed, concentrically striated basal plate. The septa are trabecular and more or less perforated, and there is either no columella or a rudimentary one.



Fig. 185.—*Cyclolites elliptica*, viewed from above, rom below, and from the side. Cretaceous.

Forming a transition between the typical *Fungida* and the typical *Perforata* is the Jurassic genus *Microsolena* (fig. 186), in which the corallum is massive, of variable shape, but usually more or less lobed. The basal wall is covered with a strong epitheca, and the calices are not circumscribed by a definite wall. The septa are trabecular and perforated, and synapticula are abundantly developed.



Fig. 186.—Fragment of *Microsolena ramosa*, and three of the calices of the same enlarged. Jurassic.

Section IV. Madreporaria Perforata.

This section includes simple or composite Madreporarians in which the calcareous tissue (sclerenchyma) of the corallum is more or less conspicuously porous or reticulate (fig. 187, c); the visceral chambers of the corallites being thus placed, in the compound forms, in communication with one another. The septa may be solid, but are usually more or less porous, being often represented by irregular trabeculæ, or, in other cases, by rows of calcareous spines. Dissepiments are usually present, and tabulæ are commonly developed. The existing *Madreporaria Perforata* fall into the three groups of the *Eupsammidæ*, *Madreporidæ*, and *Poritidæ*, while we may place here the three extinct groups of the *Favositidæ*, *Syringoporidæ*, and *Thecidæ*. These three last-mentioned groups

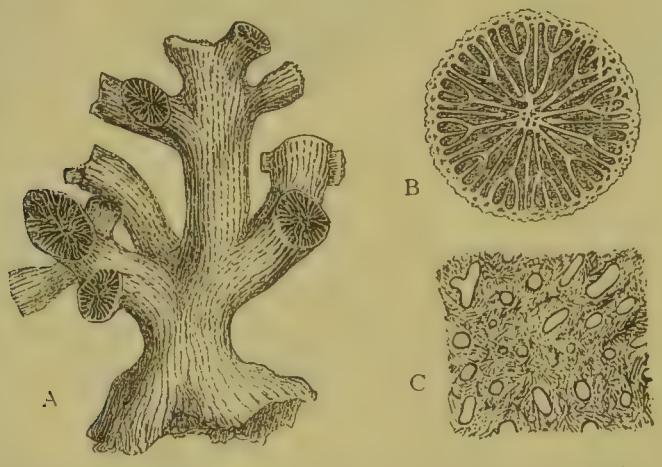


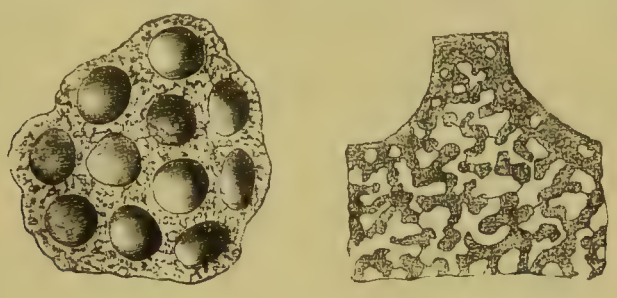
Fig. 187.—A, *Dendrophyllia elegans*, from the Oligocene Tertiary of Brockenhurst, of the natural size; B, Transverse section of the same, enlarged (after Zittel); C, Portion of a section of a recent species of *Dendrophyllia*, showing the porous structure of the skeleton.

are essentially Palæozoic, the *Favositidæ* alone having any Mesozoic representative (the *Koninckia* of the Cretaceous rocks). Of the three existing groups of the *Perforata*, the *Poritidæ* appear to be the most ancient, the Ordovician genus *Protaræa* belonging to this family, while the *Calapœcia* (*Columnopora*) of the same formation links the *Poritidæ* with the *Favositidæ*. The Devonian genera *Aræopora* and *Cleistopora*, and the Carboniferous genus *Palæacis* (fig. 188) may also be referred to the *Poritidæ*. The *Eupsammidæ* are also an ancient group, being represented in the Silurian rocks by the genus *Calostylis*. On the other hand, the *Madreporidæ* are of comparatively modern origin, the first known types appearing in the Tertiary deposits. Upon the whole, however, the existing groups of the *Eupsammidæ*, *Poritidæ*, and *Madreporidæ* do not present

themselves in any prominent manner till the Tertiary period is reached, and they have attained their maximum at the present day.

In the following brief summary of the characters and distribution in time of the leading groups of the Perforate Madreporarians, it will be best to take first the three recent families above mentioned.

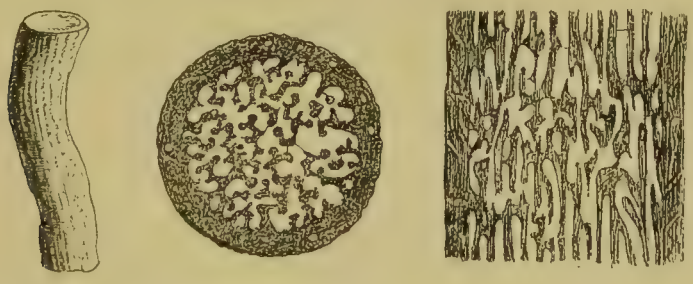
Family 1. *Eupsammidæ*.—In this family the corallum may be simple or compound, the *wall* of the corallites being perforated, while



A B

Fig. 188.—*Palæacis cyclostoma*, from the Carboniferous rocks of Scotland. A, Upper surface of a colony enlarged twice; B, Vertical section of the corallum, showing the reticulated structure of the skeleton, enlarged. (Original.)

the principal septa may be entire and imperforate. The smaller septa are, however, usually perforate, and in other cases all the septa are trabecular. There is a limited development of endothecal tissue, the interseptal loculi thus remaining more or less open. This family is principally Tertiary and Recent, but the genus *Calostylis* is Silurian, and there are also Cretaceous types (*Stephanophyllia*, &c.)



A B C

Fig. 189.—*Calostylis Andersoni*, from the Wenlock Limestone of Shropshire. A, A broken specimen, enlarged slightly; B, Transverse section, enlarged five times; C, Vertical section, similarly enlarged, showing the thick wall and the trabecular character of the septa. (Original.)

It is clear, therefore, that our knowledge of the past history of the family is extremely imperfect.

The most ancient type of this family is the genus *Calostylis*, first described by Lindström from the Wenlock Limestone of Gotland, but occurring also in deposits of the same age in Britain. In this genus the

corallum (fig. 189) is cylindrical, and may be simple, or may become composite by the production of lateral buds. The wall is thick and porous, but is covered here and there with a thin striated epitheca. The septa are so highly perforated as to become more or less trabecular (fig. 189, B and C), and they may unite centrally to form a species of spongy columella; but dissepiments are very imperfectly developed. There is no reason to doubt the correctness of Lindström's reference of *Calostylis* to the *Eupsammidæ*, with which the genus agrees in all essential characters. No type of the *Eupsammidæ* has hitherto been detected in any Palæozoic deposit of later age than the Silurian, nor in any of the older Mesozoic rock-groups; but in the Cretaceous rocks we meet with the genus *Stephanophyllia*. In this genus the corallum is free, simple, and discoid, with an open circular calice; and species of the genus range from the Cretaceous to the present day. In *Balanophyllia*, ranging from the Eocene Tertiary to the present day, the corallum is also simple, but is usually permanently fixed to some foreign body. An allied type is the Pliocene and Recent genus *Thecopsammia*, which is considered by Professor Martin Duncan to be related in some respects to the Silurian genus *Calostylis*. Also allied to *Balanophyllia* is the Eocene genus *Endopachys* (fig. 190), in which the corallum is simple and

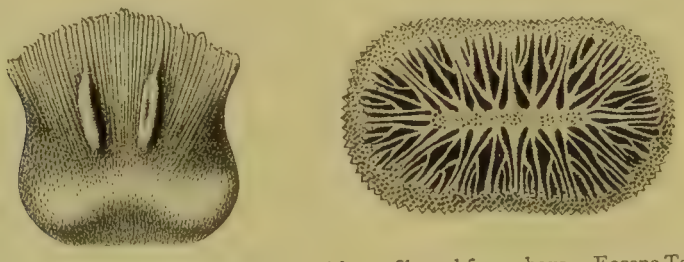


Fig. 190.—*Endopachys Maclurii*, viewed in profile and from above. Eocene Tertiary.

compressed, and a spongy columella is present, while the keeled base is continued into two wing-like expansions. The type of another group of the *Eupsammidæ* is the well-known genus *Dendrophyllia* (fig. 187), in which the corallum is composite and generally of a dendroid form, the corallites being cylindrical, and having a spongy columella. The species of *Dendrophyllia* range from the Eocene Tertiary to the present day.

Family 2. *Madreporidæ*.—In this family the corallum is invariably composite, the mode of increase being by gemmation, and the constituent corallites of the colony being united by an abundant spongy cœnenchyma. The corallites have porous walls, which are not distinct from the cœnenchyma, and the septa are usually fairly developed, and are lamellar. The interseptal loculi have dissepiments, but a columella is wanting. As here defined, the family of the *Madeporidæ* includes only the single genus *Madrepora*, including a vast number of forms, ranging in time from the Eocene Tertiary to the present day. The corallum (fig. 191) in this genus is very variable in shape, being most usually branched or tufted; the corallites are tubular, with more or less projecting calices; and the visceral cham-

ber is divided into two halves by two of the six principal septa, which are specially developed, and nearly meet along their inner edges.

Family 3. *Poritidæ*.—In this extensive family the corallum is always composite, the constituent corallites being united directly or by the intervention of a more or less copious cœnenchyma. In either case the calcareous tissue of the corallum is spongy or reticulate, and the porous walls of the corallites are mostly not separable from the



Fig. 191.—*Madrepora plantaginea*, of the natural size, showing the porous cœnenchyma and the tubular corallites. Recent.

cœnenchyma, when this latter exists. The septa may be rudimentary or obsolete, but they are usually present, and have the form of vertical rows of spinules, which often anastomose, and give rise to a sort of trellis-work. Rarely, the septa are imperforate and lamellar. In some cases tabulæ are present, and a columella may or may not be developed. The oldest types of the *Poritidæ* appear in the Ordovician rocks, but the family is represented in the Palæozoic deposits by but a few isolated genera (*Protaræa*, *Aræopora*, *Palæacis*, &c.),

and is mainly Mesozoic and Tertiary, numerous forms existing at the present day.

The group of the *Poritidæ* which is most nearly allied to the *Madreporidæ* is that of which *Turbinaria* is the type, characterised by the fact that the corallites have distinct walls and are united by an abundant reticulate or spongy cœnenchyma. *Turbinaria* itself ranges from the Miocene Tertiary to the present day, and allied types are *Actinacis* (Cretaceous to Oligocene) and *Astræopora* (Eocene to Recent). More or less closely allied to the preceding are the little Carboniferous corals which constitute the genus *Palæacis*.[1] In this genus the corallum (fig. 188) is composed of short and wide corallites, united together directly or by the intervention of a limited amount of cœnenchyma. The tissue of the skeleton is more or less trabecular (fig. 188, B), and the septa are obsolete, being represented only by rows of granules in the interior of the deep calices. The species of *Palæacis* are found growing upon the stems of Crinoids and other foreign bodies in the Lower Carboniferous rocks of both Europe and North America.

The genus *Porites* is the type of another group of the *Poritidæ*, characterised by the reticulated sclerenchyma, the almost total or total absence of a cœnenchyma, and the generally trabecular septa. The species of

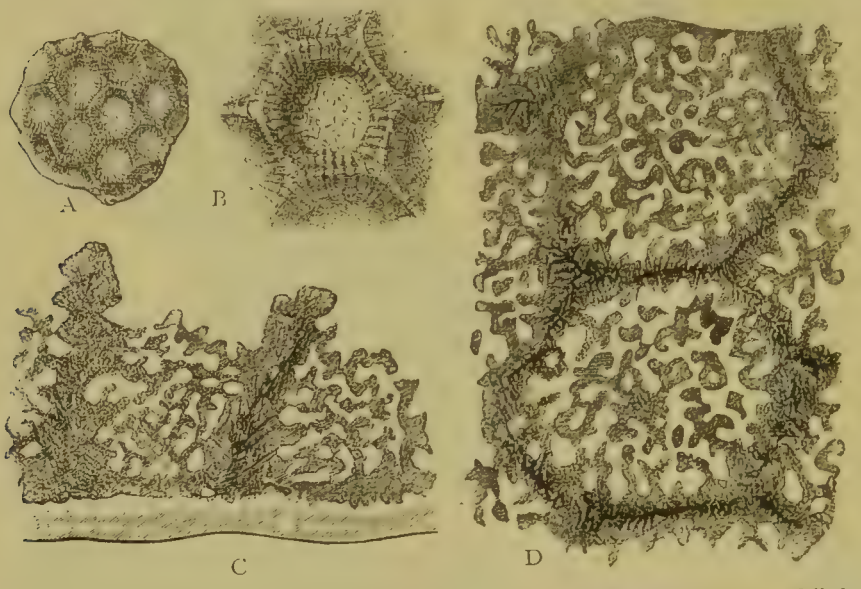


Fig. 192.—*Cleistopora geometrica*, Edw. & Haime, sp. A, Upper surface of a full-sized individual, of the natural size; B, A single calice enlarged; C, Vertical section of a specimen growing upon a Brachiopod, enlarged five times; D, Tangential section of the same specimen similarly enlarged. (Original.)

Porites are abundant at the present day, and are largely concerned with the building up of coral-reefs; while the earliest types of the genus occur in the Cretaceous rocks. Allied to *Porites* are various Tertiary

[1] Misled by certain peculiarities in the minute structure of the skeleton, the present writer was formerly induced to believe that *Palæacis* did not properly belong to the corals.

genera, such as *Litharæa*, *Rhodaræa*, &c. We may also place here the ancient genera *Stylaræa* and *Protaræa*, both of which commence in the Ordovician rocks, the latter surviving into the Devonian period. In the Devonian rocks we find, further, the singular genus *Cleistopora*, represented only by the little *C. geometrica* of the European Devonian rocks, in which the corallum (fig. 192, A) is composed of short polygonal corallites, forming a discoid colony which is usually attached by its under surface to some foreign body. The corallites are united by fusion of their walls, which are slightly porous, and the septa are only present as marginal striæ (fig. 192, B). The characteristic feature about the genus, however, is that the whole of the visceral chamber, below the calice, is filled with reticulated or trabecular calcareous tissue (fig. 192, C and D).

Lastly, a third group of the *Poritidæ* is typified by the genus *Alveopora*, the most characteristic feature of the group being that the walls of the corallites (fig. 193, A) are spongy and porous, while the septa (fig. 193, B) are trabecular, and well-developed tabulæ are usually present. The

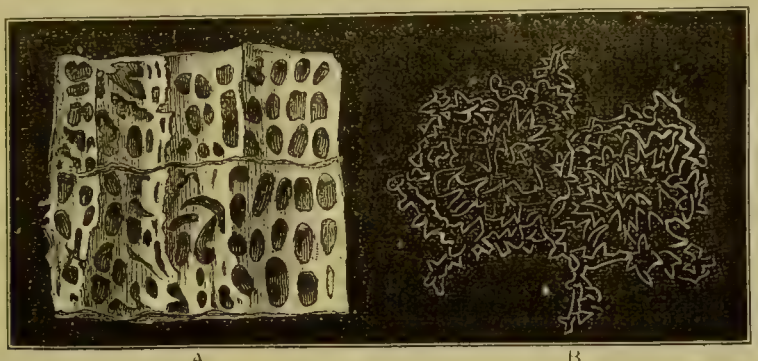


Fig. 193.—*Alveopora spongiosa*, one of the recent *Poritidæ* (after Dana). A, Some of the corallites cut vertically and enlarged, showing the tabulæ and the perforated walls; B, View of the calices from above, enlarged.

genus *Alveopora* itself ranges from the Eocene Tertiary to the present day, but the genus *Aræopora*, properly referred here by Waagen, is found in the Devonian deposits of Australia and the Carboniferous rocks of India. In this ancient type the corallum is massive, and is composed of polygonal corallites, which have their walls fused with one another. The walls are composed of spongy tissue, with irregular pores, the septa being trabecular or reticulate, while tabulæ may be more or less extensively developed. The Cretaceous genus *Koninckia*, though incompletely investigated, may also be placed here as a provisional arrangement; while the recent genus *Favositipora*, as described by Mr Saville Kent, would appear to form a connecting link between *Alveopora* and *Favosites*.

Family 4. *Favositidæ*.—This large and important family of Corals is characterised by the possession of a variably shaped corallum composed of polygonal or sub-cylindrical corallites, which are usually in close contact throughout their entire extent, but are not completely united by fusion of their walls. The walls of the corallites are porous, the visceral chambers of adjacent corallites

being thus placed in direct communication; but the perforations are not irregular, and are restricted to definite, circular or oval apertures known as "mural pores." There is no true cœnenchyma; and the condition of the septa is extremely variable, these structures being sometimes obsolete, sometimes in the form of marginal ridges, and most commonly in the form of vertically disposed rows of spinules. Tabulæ are usually well developed and complete, but

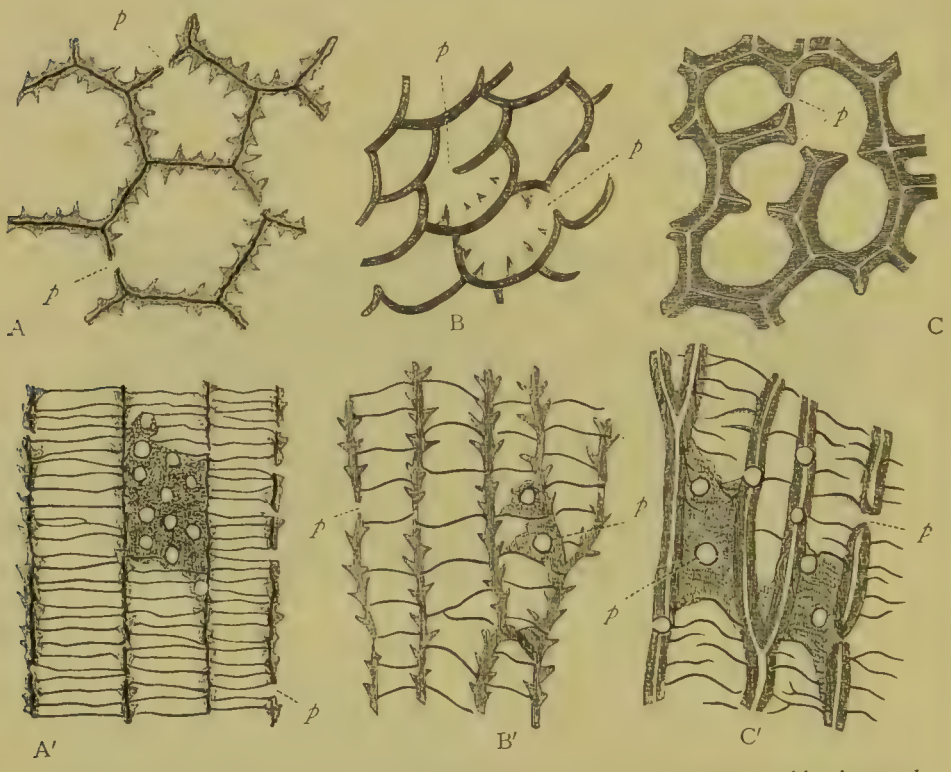


Fig. 194.—Thin sections of Favositoid Corals, showing the phenomena presented by the mural pores. A, Tangential section of *Favosites* sp., from the Devonian of Queensland, enlarged six times. A', Vertical section of the same similarly enlarged; in two of the tubes the section traverses the centre of the visceral chambers, but in one it corresponds in part with the wall of the corallite. B and B', Tangential and vertical sections of *Alveolites Labechei*, E. & H., from the Wenlock Limestone of Ironbridge, enlarged ten times. [The septal thorns which characterise this species, as also *A. Battersbyi*, E. & H., are mostly omitted in the drawing.] C and C', Tangential and vertical sections of *Pachypora* sp., from the Corniferous Limestone of the Falls of the Ohio, enlarged ten times. In all the figures the letter *p* indicates the mural pores. (Original.)

they are sometimes imperfect. The corallum increases by the form of budding which Waagen has defined as "inter-mural gemmation" (see p. 254).

The family of the *Favositidæ* is obviously allied to that of the *Poritidæ*, from which it is separated principally by the fact that the walls of adjacent corallites are not undistinguishably fused (though they may appear to be so in specimens in bad preservation), while the perforations in the walls are in the form of more or less definite

"mural pores." As here restricted, the family is exclusively Palæozoic in its range, the earliest known types appearing in the Ordovician, while the latest are found in the Carboniferous rocks. The great majority of forms, however, are Silurian and Devonian.

There are certain appearances in thin sections of the *Favositidæ*, as seen under the microscope, which it is desirable to understand. In the first place, the individual corallites of the colony have distinct walls. Hence, in thin sections (fig. 194, A and C), the partition which separates contiguous tubes usually exhibits a central dark or light line (the "primordial wall") bounded on each side by a layer of fibrous "stereoplasma." In badly preserved specimens it may not be possible to demonstrate the primordial mural plate in thin sections, but the real distinctness of the corallites is shown by the fact that in fractured examples the individual tubes commonly separate from one another along the line of this plate, each tube thus retaining its own proper wall.

In the second place, the so-called "mural pores" of the *Favositidæ* are rounded or oval apertures, usually arranged in longitudinal series, which perforate the walls of adjacent corallites and place adjoining visceral chambers in direct communication. They are sometimes not completed, since the thin "primordial wall" which separates contiguous tubes is sometimes not actually perforated. The mural pores are most regular in form and distribution in the genus *Favosites*, in which the pores are often surrounded by slightly raised margins, and are arranged in one or more series along the flat faces of the prismatic corallites (fig. 195, D). In such genera as *Pachypora*, where the corallites have greatly thickened walls, the mural pores assume the character of *tubes* rather than of mere *pores*, and in such cases they often perforate the walls in a tortuous manner. As regards their recognition in thin sections, mural pores appear in transverse sections of the tubes (fig. 194, A, B, C) as gaps or deficiencies in the wall forming the circumference of the corallite, the size of this gap depending on the size of the pores. In vertical sections (fig. 194, A′, B′, C′) the pores may similarly present themselves as gaps in the walls of the corallites. It very commonly happens, however, that a vertical section may in part *run along the actual wall* of the corallites, instead of merely dividing the tube longitudinally; and when this happens, the mural pores are seen as round or oval perforations in the wall within the space included between the lateral boundaries of the tubes.

The principal genus of the *Favositidæ* is *Favosites* (= *Calamopora*, Goldfuss) itself, the species of which range from the Ordovician to the Carboniferous inclusive. In this genus the corallum (fig. 195) is commonly massive and often of large size, but in other cases it may be lobate or branched. The corallites are numerous, usually more or less conspicuously polygonal, with thin and distinct walls. The mural pores are arranged in rows along the flat faces, or, more rarely, along the angles, of the prismatic corallites. In the former case, each face of the tube may carry one, two, or three rows of pores, this being, *generally*, a constant feature in different species. There are numerous tabulæ, and these structures are usually "complete" (*i.e.*, they stretch entirely across the visceral chamber); but

they may be "incomplete." In no instance are the tabulæ "cystoid"—that is to say, they do not anastomose so as to give rise to a vesicular tissue of arched cells. The septa in *Favosites* are sometimes wanting, but are usually represented by vertical rows of pointed tubercles or of slender calcareous spines. As previously mentioned, the tabulæ in some species of *Favosites* are "incom-

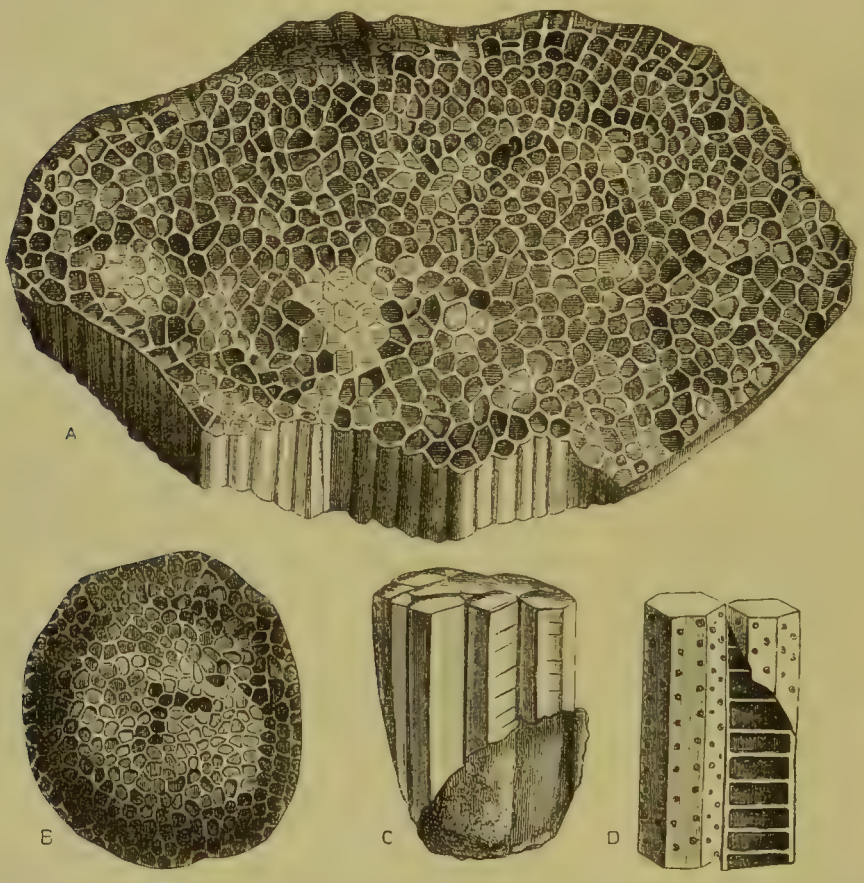


Fig. 195.—A, A specimen of *Favosites Gothlandica*, Lam., from the Niagara Limestone (Wenlock) of Owen Sound, Ontario, of the natural size; B, A small example of the same species from the Wenlock Limestone of Dudley, with comparatively minute corallites, of the natural size; C, Fragment of the same species, with large-sized corallites, from the Wenlock Limestone of Gotland, of the natural size; D, Part of two corallites of the same species, from the Corniferous Limestone (Devonian) of Woodstock, Ontario, slightly enlarged. (Original.)

plete," having the form, some or all of them, of thin, close-set transverse plates which only extend across about one-third or one-half of the diameter of the visceral chamber. This condition of the tabulæ is characteristic of such forms as the Devonian *F. hemispherica* (fig. 196), and the generic name of *Emmonsia* has been proposed for these.

Nearly allied to *Favosites* is the genus *Pachypora*, in which the

corallum is usually lobate or dendroid, and the corallites have their walls more or less extensively thickened by a secondary deposit of stereoplasma, the visceral chambers thus becoming more or less contracted, especially in the peripheral region of the colony (fig. 197).

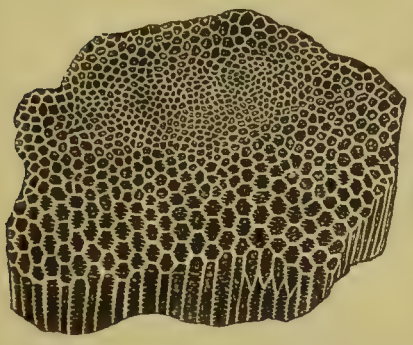


Fig. 196.—Fragment of *Favosites* (*Emmonsia*) *hemispherica*, of the natural size. Devonian, America. (After Billings.)

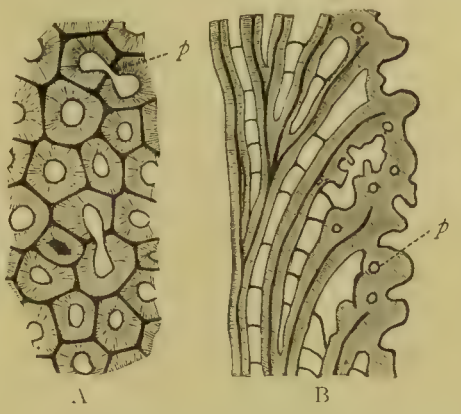


Fig. 197.—A, Transverse section of a few corallites of *Pachypora Nicholsoni*, Frech, from the Devonian of the Eifel, enlarged seven times, showing the thickened walls of the corallites; B, Vertical section of a few tubes of the same. *p*, Mural pores. (Original.)

The tabulæ in this genus are straight and complete; the septa are usually rudimentary; and the mural pores are generally large and uniserial, being converted into tubes in the more highly thickened portions of the corallites. The species of *Pachypora* are mostly Silurian and Devonian, but some forms appear to occur in the Carboniferous rocks. Closely related to *Pachypora* is the Silurian and Devonian genus *Striatopora* (fig. 198), in which the corallites also have greatly thickened walls, but the calices are surrounded by a cup-shaped thickened margin, the floor of which is striated by rudimentary septal ridges. Another allied type is the genus *Trachypora*, the species of which are principally Devonian. Here we may also place the curious Silurian genus *Laceripora*, in which the mural pores are uniserial and of large size, and the septa are in the form of marginal ridges.

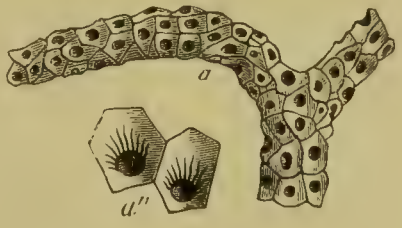


Fig. 198.—Fragment of *Striatopora flexuosa* of the natural size, and two calices enlarged. Silurian. (After Hall.)

The genus *Alveolites* is the type of another group of *Favositidæ* in which the corallites are usually more or less compressed, so as to appear triangular, or semilunar, or crescentic when transversely divided. The septa are usually present in the form of one, two,

or three elongated tooth-like ridges (fig. 199); but in some species the corallites possess strong ascending calcareous spines, the nature of which is different. The mural pores are uniserial and of large size, and the tabulæ are complete and more or less horizontal. The species of *Alveolites* usually have a branched or massive corallum, the latter usually formed of superimposed crusts; and they are found in the Silurian and Devonian deposits. An allied genus, with a similar geological range, is *Cœnites*, in which the corallites are greatly compressed, and are much thickened towards their mouths.

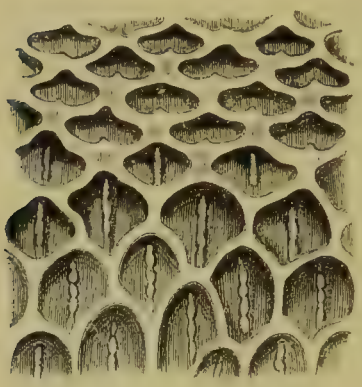


Fig. 199.—Calices of *Alveolites suborbicularis*, Lam., greatly enlarged, showing the single septal ridge. Devonian, Eifel. (After Goldfuss.)

Another group is constituted by the genera *Pleurodictyum* and *Michelinia*, in both of which the tabulæ are more or less "cystoid" or vesicular, and the mural pores are very irregular. It is, indeed, very doubtful if these two genera can be separated, and in case of their union the name of *Michelinia* will have to be abandoned. In *Pleurodictyum* (fig. 200) the corallum is discoid; with a flat or concave base, covered with an epithecal plate, and attached at one point to a foreign body. The corallites are polygonal, and diverge from the centre of the base, those on the circumference being nearly horizontal or even bent downwards, while the median ones are more or less perpendicular. The mural pores are numerous and quite irregular; and in one species there is the singular feature that the mural pores of the under sides of the peripheral corallites pass directly through the basal plate of the colony, which thus becomes perforated. The tabulæ often inosculate, and become to some extent vesicular, but these structures are comparatively few in number, and the "cystoid" character of the tabulæ is thus little marked. The genus *Pleurodictyum* is wholly Silurian and Devonian, so far as known, if *Michelinia* be excluded from it. The best known species is the *P. problematicum* of the Devonian rocks of Europe, the singular discoid casts of which (fig. 200, A) are commonly found in the Lower Devonian of the Eifel. In these casts the conical columns (fig. 200, B) represent the moulds of the visceral chambers of the corallites, and the little cylindrical rods connecting these are the result of the infilling of the mural pores. A singular feature in these casts is, that there is generally to be seen a curious cylindrical twisted body (fig. 200, A) in the centre of the base. This "worm-like body" has been very generally recognised in specimens of

Pleurodictyum, of different species and from widely remote regions. There is little reason to doubt that it represents the tube of an Annelide which lived as a "commensal" with the coral, in the same

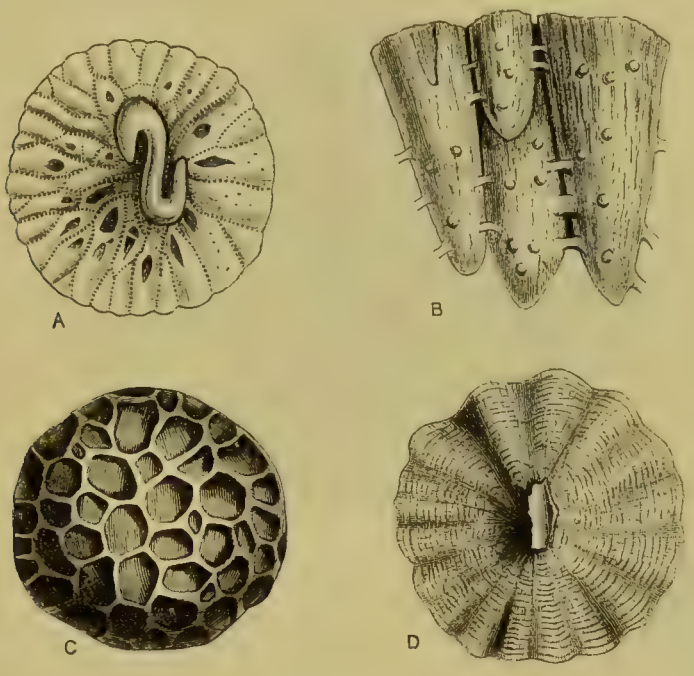


Fig 200.—A, Lower surface of the cast of *Pleurodictyum problematicum*, Goldf., from the Lower Devonian of Germany, of the natural size (after Roemer), showing the vermiform body in the centre; B, A few of the separate casts of the tubes of *Pleurodictyum problematicum*, Goldf., from the Devonian of the Eifel, showing the casts of the mural pores, enlarged (after Milne-Edwards and Haime); C, Upper surface of the corallum of *Pleurodictyum stylophorum*, Eaton, from the Hamilton group of North America, of the natural size, showing the form of the calices (Original); D, Lower surface of another example of the same, of the natural size, showing the striated epitheca, and the point where the corallum was attached to the stem of a Crinoid (Original).

way as a Sipunculid (*Aspidosiphon*) is found in constant association with the corallum of the existing *Heteropsammia*.

The genus *Michelinia* is in all its essential characters identical with *Pleurodictyum*, but the corallum is massive (fig. 201), and the tabulæ are numerous, and inosculate so as to give rise to a tissue of arched vesicles. The epitheca, also, commonly gives off root-like processes of attachment. The species of *Michelinia* are all Devonian and Carboniferous.

It remains to briefly notice certain transitional types by which the *Favositidæ* are connected with the *Poritidæ* on the one hand and the *Syringoporidæ* on the other hand. Thus, a near approach to *Alveopora* among the *Poritidæ* is effected by the remarkable Ordovician genus *Calapœcia* (=*Columnopora*).[1] The corallum in this genus is massive, and is com-

[1] An examination of the original specimens has clearly shown that the forms described by Billings under the name of *Calapœcia* are identical with those

posed of polygonal corallites, which are usually directly connected by their walls, and agree with those of the *Favositidæ* in possessing a primordial mural plate. A true cœnenchyma is in general wanting, but in some

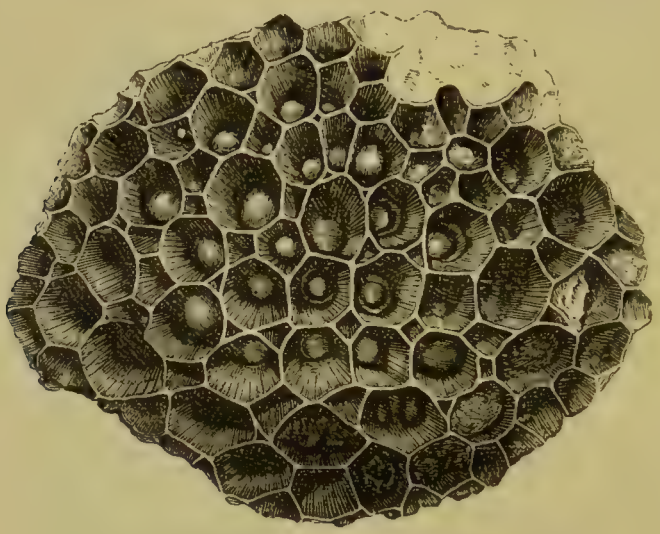


Fig. 201.—*Michelinia convexa* (D'Orbigny). Devonian.

specimens the corallites are in places connected by the intervention of a small quantity of exothecal tissue. The walls of the corallites are perforated by rows of large mural pores, which are placed close together and give the wall a lattice-like appearance. The septa are in the form of

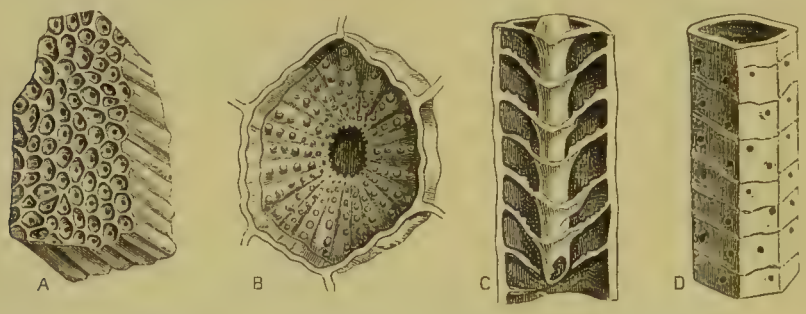


Fig. 202.—A, A fragment of a colony of *Syringolites Huronensis*, Hinde, of the natural size; B, A single calice of the same, enlarged eight times, showing the central tube, and radiating lines of septal tubercles; C, Part of a corallite of the same, split open, and enlarged six times, showing the composition of the central tube out of invaginated tabulæ; D, Part of a corallite of the same, viewed from the exterior and enlarged six times, showing the mural pores. Niagara Limestone, Manitoulin Island, Ontario. (Original.)

marginal ridges, and the tabulæ are complete and horizontal, and do not give rise to a vesicular tissue by their union.

described by the present writer under the head of *Columnopora*, and the latter name must therefore be abandoned. Of the forms included by Billings under *Calapœcia*, only one—viz., *C. Anticostiensis*—was figured, and this proves to be really quite different from the others, and to be nearly related to the genera *Syringophyllum* and *Thecostegites*.

On the other hand, a distinct transition between *Favosites* and *Syringopora* is effected by the Silurian genus *Syringolites*, in which the corallum (fig. 202) is quite similar in general structure to *Favosites*, being composed of thin-walled polygonal corallites, the faces of which are perforated by longitudinal rows of distant mural pores, but the tabulæ are curved, and are depressed centrally so as to produce by their invagination a vertical median tube running down the middle of each visceral chamber. The Devonian genus *Roemeria*, again, seems to offer a similar transition between *Pachypora* and *Syringopora*. In this remarkable type, the corallum is closely similar in general structure to that of *Pachypora*, being composed of contiguous polygonal corallites, with distinct walls which are greatly thickened internally by a secondary deposit of stereoplasma, and are perforated by well-marked tubular mural pores, but the tabulæ are funnel-shaped and are invaginated in a manner precisely similar to that which is so characteristic of *Syringopora*.

The genus *Romingeria*, of the Silurian and Devonian rocks of North America, affords another transitional link between the *Favositidæ* and the *Syringoporidæ*. The corallum in this genus (fig. 203) is lax and spreading, erect or semi-erect, and composed of cylindrical tubular corallites which are produced by gemmation in umbellate whorls or verticils. The tubes are largely free, but where their walls come in contact, the visceral chambers are placed in communication by distinct mural pores. The tabulæ are remote, and in general horizontal, and the septa are represented by vertical rows of calcareous spines.



Fig. 203.—Portion of the corallum of *Romingeria umbellifera*, of the natural size. Devonian (Corniferous Limestone), Canada. (Original.)

Family 5. *Syringoporidæ*.—This family includes a number of Palæozoic corals in which the skeleton is composite, usually fasciculate in form (figs. 204-207), and is composed of cylindrical corallites which in general are not in actual contact, but mostly have their visceral chambers placed in direct communication by means of hollow, cylindrical connecting-processes or horizontal platforms, which are periodically produced. In many cases the corallites come into actual contact in parts of the corallum, and where this occurs their walls are pierced by mural pores similar to those of the *Favositidæ*. The tabulæ are well developed, and are usually funnel-shaped, but they are sometimes vesicular, or may, rarely, be simply curved. The septa are in the form of vertical rows of calcareous spines. The mode of increase is by basal or stolonal gemmation, or by the production of new buds from the connecting-processes or floors. The oldest members of this family appear in the Ordovician rocks, and the last appear in the Carboniferous.

The affinities of the *Syringoporidæ* have been much disputed, and the type-genus *Syringopora* has commonly been placed among the *Alcyonaria*, and has been regarded as a near ally of the recent

Tubipora. To the present writer the evidence in favour of the view that the *Syringoporidæ* constitute a peculiar group of the *Madreporaria Perforata*, and that they are nearly related to the *Favositidæ*, appears to be exceedingly strong, and may be briefly summed up as follows :—

a. The hollow connecting-processes of *Syringopora* are morphologically nothing more than mural pores as existing between corallites which are not in actual contact, and, like mural pores, they place the visceral chambers of contiguous tubes in direct communication.

b. In many members of the *Syringoporidæ* the corallites *do*



Fig. 204.—*Syringopora retiformis*. Silurian.

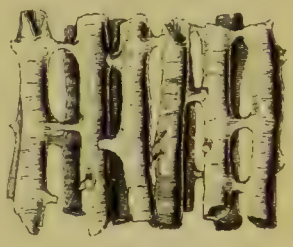


Fig. 205.—*Syringopora verticillata*. Silurian.



Fig. 206.—*Syringopora Dalmani*. Silurian.

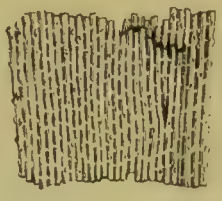


Fig. 207.—*Syringopora compacta*. Silurian.

partially come into direct contact, and wherever this occurs, mural pores of the ordinary Favositoid type are developed.

c. The septa have the form of vertical rows of calcareous spines, as is also the case in the typical members of the *Favositidæ*.

d. The Favositoid genera *Syringolites* and *Roemeria* possess the infundibuliform tabulæ of *Syringopora* in combination with the contiguous corallites and serially disposed mural pores of *Favosites* and *Pachypora*.

e. On the other hand, the Syringoporoid genera *Cannapora*, *Chonostegites*, *Thecostegites*, and *Syringophyllum* have the general characters of *Syringopora* as regards the form of the corallum and the mode of increase, but resemble different members of the *Favositidæ* in the characters of the tabulæ, and, occasionally, in the possession of "mural pores."

f. Lastly, the skeleton in *Syringopora* and its allies is never composed of spicules, as it is in *Tubipora*, but its microscopic structure agrees precisely with that of the corallum in the *Madreporaria* generally.

It should be added, however, that though it would appear highly probable that the real affinities of the *Syringoporidæ* are with the *Madreporaria*, the members of this family show a resemblance to the Alcyonarians in the fact that their common mode of increase is by stolonal or basal gemmation, and in this respect they differ altogether from the typical Perforate Madreporarians; though this single feature cannot be allowed to counterbalance their numerous and striking points of resemblance to the *Favositidæ*.

The typical genus of the *Syringoporidæ* is *Syringopora* itself, in which the corallum commences as a prostrate network of tubes, resembling in form a colony of *Aulopora*. In process of growth, this basal network sends up numerous vertical, flexuous, cylindrical corallites, which are not in direct contact, though sometimes (*e.g.*, in *S. laxata*) they become directly united here and there. The corallites are enclosed, each, in a thick proper wall, and they are usually united by hollow cylindrical connecting-processes (figs. 204-207) which occasionally (*e.g.*, in *S. tabulata*) assume the form of horizontal laminar floors. These connecting-processes place the visceral chambers of adjoining tubes in direct communication, and, as shown in thin sections (fig. 208), they are traversed by continuations of the endothecal tissue of the polypes themselves. The septa are sometimes nearly obsolete, but they usually have the form of vertical rows of calcareous spines. The tabulæ are well developed, and are in general more or less regularly funnel-shaped (fig. 208, A), and give rise by their invagination to a more or less continuous tube occupying the axis of the visceral chamber. The species of *Syringopora* are abundant in the Silurian, Devonian, and Carboniferous deposits, and often reach a large size.

In the Silurian genus *Cannapora*, the general form of the corallum is like that of *Syringopora*, but when connecting-processes are present these are very short, and the corallites are usually partially in contact, in which case they assume a polygonal form and are perforated by mural pores. The tabulæ are sometimes funnel-shaped, sometimes simply curved, and the septa are spiniform.

We may also include in this family the remarkable Devonian genus *Chonostegites*, which proves to be a link between the *Syringoporidæ* and *Favositidæ*, and has, indeed, been included in the latter family. The corallum in this genus is massive, and is composed of cylindrical corallites which may be partially in contact, but are usually separate and are connected by numerous close-set, concentrically disposed, horizontal connecting-floors or laminar expansions. These periodic floors are so far exothecal that they are extensions from the walls of the corallites, but they are hollow, and are filled with prolongations of the endothecal tissues of the corallites themselves, so that they place the visceral chambers of contiguous tubes in direct communication. In places, the corallites come into direct contact, and in this case their visceral chambers communicate by mural pores precisely similar to those of the *Favositidæ*. The septa have the form of rows of calcareous spines, and the tabulæ differ from those of *Syringopora* and

agree with those of *Michelinia* in being vesicular or "cystoid" in structure. The increase of the corallum is by basal gemmation, or by budding from the hollow periodic expansions in the intervals between the old cups. In the mode of increase, *Chonostegites* resembles *Syringopora*, and the hollow periodic floors may be considered as homologous with the hollow connecting-tubes of the latter. On the other hand, in the possession of vesicular tabulæ and in the presence of mural pores in parts where the corallites touch each other, the genus closely approaches to *Michelinia*. Nearly related to *Chonostegites* is the Ordovician and Silurian genus *Syringophyllum*, and we may also place here the Devonian genus *Thecostegites*. In both these genera the corallum consists essentially of cylindrical, tabulate corallites which are placed in connection with one another by hollow, periodically produced, laminar floors, into which the endothecal tissues of the polypes are directly continued; but in some cases these floors are successively superimposed on one another, and give rise by their union to a kind of spurious cœnenchyma. The structure of the skeleton in these genera is, however, too complex to allow of its being advantageously considered here.

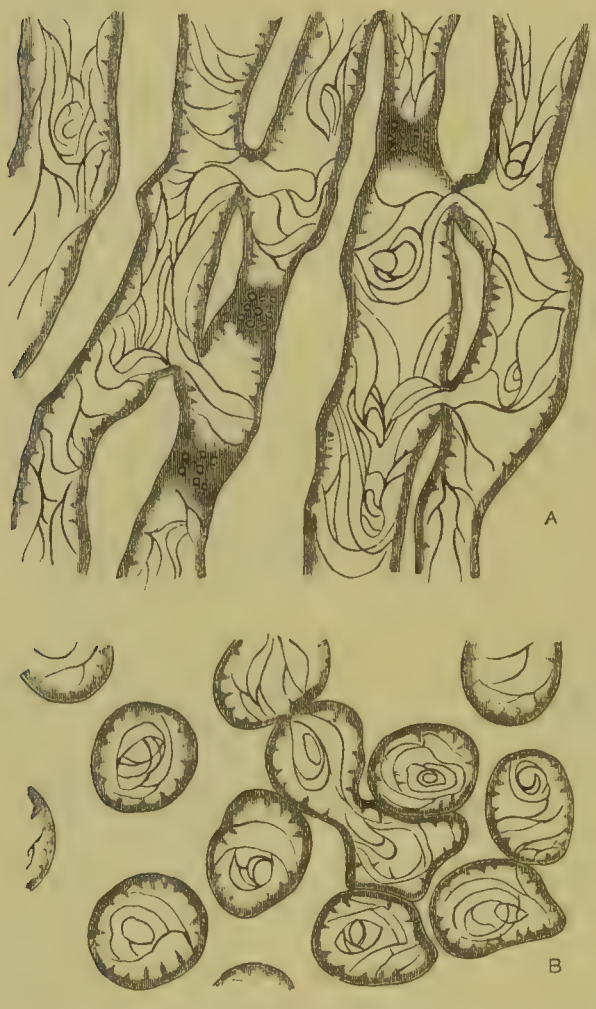


Fig. 208.—A, Part of a longitudinal section of *Syringopora reticulata*, Goldf., from the Carboniferous Limestone of Kendal, Westmorland, enlarged five times, showing the spiniform septa and the funnel-shaped tabulæ with their central tube. Owing to the flexures of the corallites, the section cuts the tubes in different parts, sometimes passing close to the wall and showing the cut ends of the spiniform septa, sometimes passing through the axis of the visceral chamber and bisecting the axial tube, and sometimes cutting the axial tube and its enveloping tabulæ in an oblique manner. B, Part of a transverse section of the same specimen, enlarged five times, showing the spiniform septa, and the cut edges of the tabulæ surrounding the central tube. (Original.)

Family 6. *Thecidæ*.—This family includes only the aberrant genus *Thecia*,[1] the structure of which is too complex to permit of more than

[1] As the result of extended investigations, the writer has been led to materially modify the views which he formerly expressed ('Palæozoic Tabulate Corals') as

the briefest description in this place. The corallum in *Thecia* is generally in the form of a laminar expansion, furnished inferiorly with a striated epithecal membrane. In their early condition, the corallites are often oblique to the basal plate, and in this stage they have thin and apparently distinct walls, the visceral chambers being crossed by complete tabulæ, and the general appearance being not unlike to that of some species of *Favosites*. Very soon, however, the corallites become perpendicular to the basal plate, and they then appear to lose their distinct walls and to become united by the intervention of a thick, vertically tubulated calcareous tissue, which may be regarded as probably of the nature of a spurious cœnenchyma, and from which the walls of the individual corallites are wholly inseparable. The surface, therefore, exhibits the stellate calices of the corallites separated by an apparently dense interstitial tissue, marked superficially by minute tubercles, and by radiating, often vermicular, grooves which extend from one calice to another. The visceral chambers of adjacent corallites are placed in direct communication by means of well-marked, often bent, horizontal tubes, which represent elongated mural pores. The septa are generally twelve in number in each corallite, and have the form of irregular vertical ridges, with very broad bases, which only extend a short way inwards into the visceral chamber, and appear sometimes to terminate along their inner edges in blunt spines. The tabulæ are complete, horizontal, or slightly curved, and tolerably numerous.

The known species of *Thecia* are Silurian, the most familiar being the common *T. Swindernana* of the Wenlock Limestone. The coral described by Rominger from the corresponding horizon in America under the name of *Thecia major* appears to differ in important respects from the European species of *Thecia*, and would appear to be nearly related to the Favositoid genus *Laceripora*.

The family of the *Thecidæ*, as above defined, is separated from the *Favositidæ* by the complete fusion of the corallites in the terminal portion of their course, and by the peculiar nature of the tubulated cœnenchymal tissue which separates adjoining visceral chambers. The fact that the corallites have as a rule twelve septa each, would support the view that *Thecia* is to be regarded as referable to the *Zoantharia* rather than to the *Alcyonaria;* and the presence of tubes directly connecting the cavities of adjoining polypes would show that the genus belongs to the *Madreporaria Perforata*.

to the structure and affinities of *Thecia*. The exothecal tubules were previously regarded as corresponding with the "mesopores" of *Heliolites*, and the genus was on this ground placed among the *Alcyonaria*. The examination of well-preserved specimens by means of thin sections would, however, appear to prove conclusively that this is not their nature, and that they are really what Milne-Edwards and Haime described as a "spurious cœnenchyma."

CHAPTER XX.

GENERAL CHARACTERS AND DIVISIONS OF THE ALCYONARIA.

The second great division of the *Actinozoa* is that of the *Alcyonaria* or *Octactiniæ*, defined by the possession of *polypes with eight pinnately fringed tentacles, the mesenteries and intermesenteric chambers being also eight in number. The corallum is usually sclerobasic, or spicular, or formed of both an axial sclerobasis and detached spicules. In other types, the polypes composing the colony may be provided with separate "thecæ."*

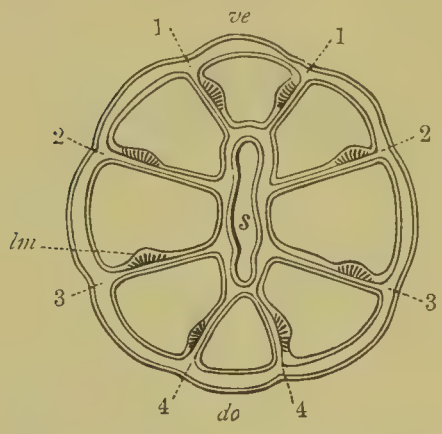


Fig. 209.—Transverse section of a polype of *Alcyonium*, enlarged. (After O. and R. Hertwig.) The numbers indicate the four pairs of mesenteries. *s*, Œsophagus transversely divided; *lm*, One of the eight longitudinal "retractor" muscles of the mesenteries; *ve*, Ventral side of polype; *do*, Dorsal side. Nos. 1 1, and 4 4, are the "directive" mesenteries.

The *Alcyonaria* are essentially distinguished from the *Zoantharia* by the possession of eight unpaired mesenteries and eight tentacles (reduced in some rare cases to six or four).

The mesenteries (fig. 209) are symmetrically grouped round the œsophagus, so that there is a dorsal intermesenteric space, and a ventral one, together with three lateral compartments on each side. The "directive" mesenteries of the ventral side (fig. 209, Nos. 1, 1), have the longitudinal retractor muscles attached to their opposed faces; whilst the opposed sides of the dorsal directive mesenteries have the transverse muscles. The mesenteries are not in pairs; and the order in which they appear has not been precisely investigated, the numbering given in the annexed figure not being certainly known to express the order in which these structures are developed.

With the exception of the two genera *Monoxenia* (*Haimeia*, E. and H.) and *Hartea*, the *Alcyonaria* are all composite, the tubular polypes being united by a cœnosarc, and their body-cavities being placed in communication by means of anastomosing canals, which ramify in the cœnosarc, and permit of a free circulation of nutrient fluids. The form of the colony differs greatly in different cases, but none possess the power of independent locomotion, most being rooted to foreign objects, or sunk in the mud. The polypes, in most of the essential points of their organisation, agree with those of the *Zoantharia*, the mouth opening into a tubular gullet, which in turn communicates freely with the body-cavity, and the œsophagus being connected with the body-wall by means of a series of vertical membranous laminæ or "mesenteries." The mesenteries, however, are only eight in number, and are not paired, one of the tentacles corresponding with and opening into each intermesenteric chamber.

The gullet in the *Alcyonaria* is so placed that its long axis (fig. 209) corresponds with the dorso-ventral plane of the body of the polype, and it very commonly is furnished on its ventral side with a ciliated groove (the "siphonoglyphe" of Mr Hickson).

In many instances the colony in the *Alcyonaria* is dimorphic, consisting of two sets of zoöids, which differ from one another in structure and function. The zoöids of the one series (generally called "autozoöids) have the normal size, and possess the structures proper to the mature polypes; while those of the other series (generally called "siphonozoöids") are reduced in size, and want certain structures of the normal polypes, such as tentacles, mesenterial filaments, or reproductive organs. No siphonozoöids have been recognised in *Tubipora* or in most of the *Gorgonidæ*, and von Koch doubts if the structures described as such by Moseley in *Heliopora* are really of this nature.

The mode of increase in the *Alcyonaria* is typically by basal or stolonal gemmation, the parent throwing out basal extensions, which commonly unite to form a creeping network or a crust-like expansion, from which new polypes are thrown up at intervals. In other cases the stolons are produced from the sides of the polypes at different levels above the base; and in still other cases (*e.g.*, in *Alcyonium*) the stolons coalesce to form a common fleshy mass or cœnosarc. In some cases, as in the *Heliolitidæ*, the peculiar mode of increase which has been described by von Koch as "cœnenchymal gemmation" is observed, but the nature of this will be described hereafter.

There are no skeletal structures in *Monoxenia* (*Haimeia*), but with this exception a corallum of some sort or another is produced in all the *Alcyonaria*. According to the investigations of von Koch, the skeletal structures of the *Alcyonaria* may be ectodermal or mesodermal in origin. The ectoderm commonly produces hard struc-

tures of a horny character, in general hardened by the deposition of carbonate of lime. In some cases (*e.g.*, in *Cornularia*) these horny structures remain external, forming a sheath to the colony; but in other cases the colony becomes in process of growth inverted over the skeleton, which then forms a central horny axis or "sclerobase" supporting the soft parts (fig. 210). The mesoderm may also produce skeletal structures in the form of variously-shaped crystalline spicules or "sclerites" (fig. 123), which are composed of an organic basis hardened by carbonate of lime. In some Alcyonarians the skeleton consists solely of these mesodermal spicules, which may remain entirely free and detached (as in *Alcyonium*), or may be fused with one another directly (as in *Corallium* and *Tubipora*), or may be partly free and partly united by horny matter (as in *Sclerogorgia*). In other types, again, as in *Gorgonia* and *Isis*, the skeleton is twofold, consisting on the one hand of an axial sclerobase of ectodermal origin, and on the other hand of free spicules developed within the mesoderm. The skeleton of *Heliopora*, finally, is peculiar in its structure, and is probably ectodermal in origin.

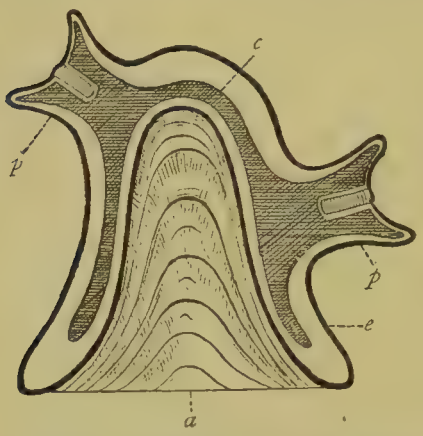


Fig. 210.—Diagrammatic vertical section through a young colony of *Gorgonia*, showing the relation of the sclerobase to the soft parts. *a*, Horny axis or sclerobase, supporting the colony; *e*, Ectoderm represented by the thick dark line; *p p*, Two polypes; *c*, One of the cœnosarcal canals, connecting the visceral chambers of the polypes with one another. For the sake of clearness, the horny axis has been represented of disproportionate thickness. (After von Koch.)

The *Alcyonaria*, so far as the living types are concerned, are divided by von Koch into the following groups:—

Sub-order I. Alcyonacea.—Sedentary Alcyonarians in which an axial skeleton is usually wanting. When such a skeleton exists (as in *Corallium*) it is of mesodermal origin, and is not secreted by a continuous epithelial layer.

Family 1.	Haimeidæ, . . .	*Monoxenia, Hartea.*
" 2.	Cornularidæ, . .	*Cornularia, &c.*
" 3.	Alcyonidæ, . . .	*Alcyonium, &c.*
" 4.	Pseudaxonia, . . .	*Corallium, Mopsea, &c.*
" 5.	Tubiporidæ, . . .	*Tubipora.*
" 6.	Helioporidæ, . . .	*Heliopora.*

Sub-order II. Gorgonacea.—Sedentary Alcyonarians in which there is a firm sclerobasic axis secreted by a continuous epithelial layer. The colony is not polymorphic.

Family 7.	Gorgonidæ, . . .	*Gorgonia, Isis, &c.*

Sub-order III. Pennatulacea.—Free-living Alcyonarians consisting of a stem and polypiferous branches. The colony is polymorphic.

Family 8. Pennatulidæ, . . . *Pennatula*, *Veretillum*, &c.

So far as the sub-orders are concerned, the above classification is only partially available for palæontological purposes, as based upon characters which are not recognisable in fossil forms. There are, moreover, certain extinct groups of corals (*Halysitidæ*, *Tetradiidæ*, *Chætetidæ*, &c.) which we must provisionally place among the Alcyonarians, but which cannot, with our present knowledge, be included in any of the three sub-orders above mentioned.

As regards the *distribution in time* of the Alcyonarians, the families of the *Haimeidæ*, *Cornularidæ*, *Alcyonidæ*, and *Tubiporidæ* have no fossil representatives, so far as is certainly known; and only the last mentioned of these requires further notice here. On the other hand, the families of the *Pseudaxonia*, *Gorgonidæ*, *Pennatulidæ*, and *Helioporidæ* are all sparingly represented by fossil types in the Secondary and Tertiary deposits. The extinct family of the *Heliolitidæ* is mainly Palæozoic, its earliest representatives appearing in the Ordovician rocks. In addition to the preceding, there are the four families of the *Halysitidæ*, *Tetradiidæ*, *Chætetidæ*, and *Auloporidæ*, the members of which are apparently exclusively Palæozoic, but the true relationships of which are more or less uncertain. Still more uncertain is the systematic position of the extinct groups of the *Monticuliporidæ* and *Fistuliporidæ*, which will be here treated of apart from the *Alcyonaria*.

In the following brief account of the fossil Alcyonarians, only those families will be considered which are known to have fossil representatives; but the family of the *Tubiporidæ* also demands a short notice, from its supposed relationship to *Syringopora*.

Pseudaxonia.

This group of the Alcyonarians comprises forms in which the skeleton is composed of mesodermal spicules, the sclerobasic axis, when present, not being secreted by a continuous epithelial layer. The spicules are sometimes (*Briareum*) completely detached, though even in this case they may form in part a tolerably well-defined axis. On the other hand, in the well-known Red Coral (*Corallium rubrum*) there is a dense calcareous sclerobase which is composed of spicules or sclerites embedded in and united by a fibro-crystalline calcareous matrix (fig. 211). The sclerobasic axis of *Corallium* is unjointed and is branched, and its surface exhibits longitudinal grooves which lodged the larger cœnosarcal canals (fig. 124). In *Melithæa* and *Mopsea*, again, there is a sclerobasic axis, but this is jointed, and is com-

posed alternately of soft and hard segments, the former being composed of separate sclerites united by horny matter, while the latter are made up of fused spicules. In *Sclerogorgia*, finally, there is an unjointed axis, consisting of horn with embedded sclerites, while there are also free spicules in the soft tissues.

As regards the geological distribution of the *Pseudaxonia*, the genus *Corallium* appears to be represented in rocks as ancient as

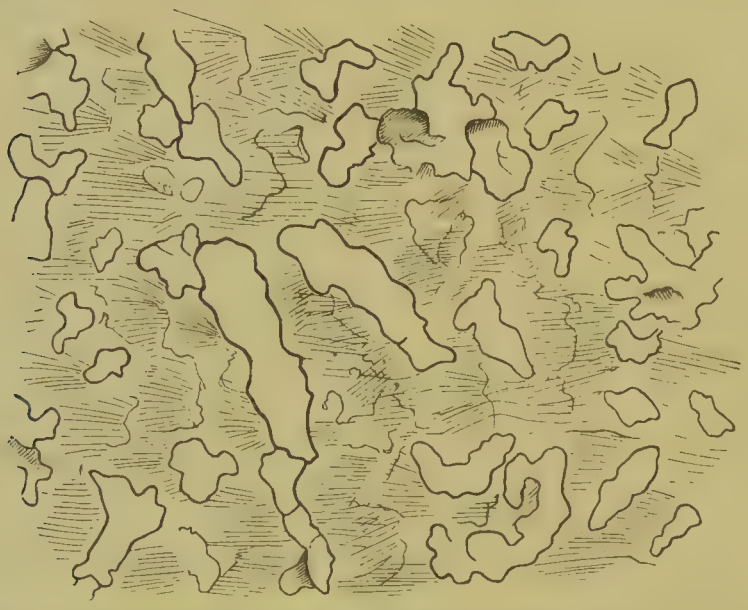


Fig. 211.—Part of a longitudinal section of *Corallium rubrum*, magnified 180 times, showing the spicules of the skeleton united by a crystalline or fibrous matrix, produced by the calcification of the soft interspicular tissues. (Original.)

the Jurassic, and the Eocene Tertiary has yielded the remains of the genera *Mopsea* and *Websteria*, of which the former still survives, while the latter is confined to the Eocene and is of uncertain affinities.

Tubiporidæ.

This group of the Alcyonarians comprises only the recent genus *Tubipora*, including the familiar "Organ-pipe Corals." There is a well-developed corallum in *Tubipora* composed of numerous cylindrical tubes or thecæ, separated by small intervals, and connected with one another by horizontal calcareous floors, which form a series of concentric laminæ parallel with the upper surface of the colony. These floors are produced by the coalescence of horizontal stolons given out from the upper ends of the polypes, and new corallites are budded out from their upper surface. Internally they are traversed by horizontal canals which communicate with the visceral chambers

of the polypes by numerous rounded apertures placed at the points where the corallites are embraced by the floors (fig. 212, A and B).

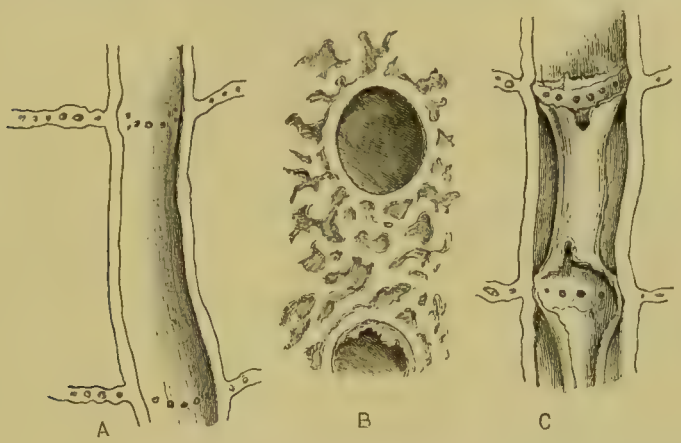


Fig. 212.—A, Part of a tube of *Tubipora musica*, Linn., divided longitudinally, showing the openings of the canal-system of the connecting-floors into the visceral chamber of the polype; B, Part of a horizontal section taken at the level of one of the connecting-floors, showing the canal-system of the connecting-floor; C, Part of a corallite of *Tubipora* divided longitudinally, showing the axial tube; in the lower portion of the figure the axial tube is laid open. All the figures are enlarged five times. (Original.)

In the interior of the corallites there commonly exists a hollow calcareous tube (fig. 212, C), which occupies the axis of the visceral

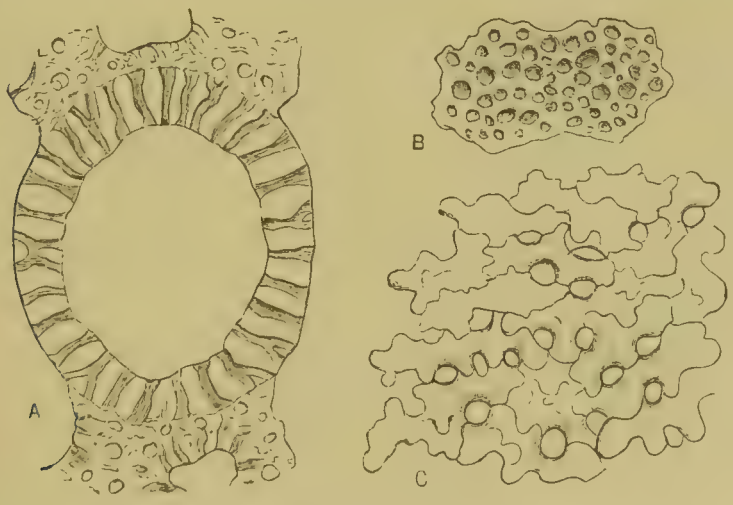


Fig. 213.—A, Transverse section of a corallite of *Tubipora musica*, Linn., taken at the level of one of the connecting-floors, enlarged twenty times, showing the tubuli of the wall; B, Portion of the surface of one of the connecting-floors, enlarged twenty times, showing the external openings of the tubuli of the skeleton; C, Fragment of the corallum of *Tubipora*, enlarged sixty times, showing the composition of the skeleton out of spicules. (Original.)

chamber, and is dilated and fused with the enclosing theca at the level of the successive connecting-floors. This axial tube is only

occasionally present; and no traces of proper "tabulæ" (in the strict sense) have been noticed to occur. There are also no structures which admit of being regarded as septa.

As regards the microscopic structure of the corallum of *Tubipora*, the entire calcareous skeleton is permeated throughout by a system of minute parallel tubules, which sometimes branch, and which open on the surface by well-defined rounded apertures (fig. 213, A and B). These canaliculi run at right angles to the walls of the corallites and also to the connecting-floors, and they render the skeleton of *Tubipora* completely and minutely porous. Moreover, thin sections show that the skeleton is made up of a network of irregular fusiform spicules which are firmly united with one another (fig. 213, C).

The genus *Tubipora* is not known to occur in a fossil condition, but the structure of its skeleton is a matter of considerable palæontological importance, as high authorities regard the genus as the closest living ally of the Palæozoic genus *Syringopora*. Reasons have been previously given (p. 320) for considering that *Syringopora* and its allies are closely related to the *Favositidæ*, and that they truly form a group of the *Madreporaria Perforata*. It is sufficient, therefore, to point out here that the skeleton of *Tubipora* differs fundamentally from that of *Syringopora* in the following points:—

a. The entire skeleton is traversed by minute canaliculi, no traces of which are found in the compact corallum of *Syringopora*.

b. The skeleton is composed of distinct spicules.

c. The axial tube, when present, is not formed of invaginated "tabulæ," as in *Syringopora*, and there is no evidence of the existence of proper "tabulæ" at all.

d. No proper septa exist, whereas well-developed spiniform septa are present in *Syringopora*.

Upon the whole, therefore, it would appear that there is no sufficient evidence at present available which would support the reference of *Syringopora* and its allies to the *Tubiporidæ*.

Gorgonidæ.

The family of the *Gorgonidæ*, as defined by von Koch, includes those Alcyonarians in which the colony is fixed, and is supported by an axial sclerobase, which is secreted by a continuous layer of epithelium. The sclerobase may be purely horny (as in *Gorgonia* itself), or it may be composed of alternate horny and calcareous joints (as in *Isis*). The polypes are all similar to one another, and polymorphism has not been observed. This family is of little palæontological importance; but the genus *Isis* has been recognised in deposits as ancient as the Cretaceous. Remains re-

ferable to the recent genera *Primnoa* and *Gorgonella* have also been detected in the Miocene Tertiary rocks.

PENNATULIDÆ.

This family includes a number of Alcyonarians in which the colony is not fixed to any foreign object, and is composed of a central cœnosarcal stem or rachis carrying polypes superiorly, these being commonly arranged on longer or shorter lateral branches. The polypes are dimorphic, and the skeleton usually has the form of an unbranched, horny or partially calcified sclerobase. This group is also of small palæontological importance, but the genus *Pavonaria* has been recognised in deposits of late Cretaceous age, and the remains of *Graphularia* have been found in the Eocene and Miocene Tertiary.

HELIOPORIDÆ.

This family, as here defined, comprises only the single genus *Heliopora*, in which there is a well-developed sclerodermic corallum (fig. 214, A) composed of tabulate tubes of two sizes, the larger of these being furnished with radiating pseudosepta, which do not correspond in number with the mesenteries of the living polypes. The larger tubes of the colony ("autopores") have usually been regarded as the true corallites, and the smaller interstitial tubes ("siphonopores") have been commonly considered as constituting a "cœnenchyma"; but the researches of Moseley on the living *Heliopora cærulea* have rendered it probable that the colony is really dimorphic, the sexual zoöids occupying the large tubes, while the small tubes lodge imperfect sexless zoöids. The large tubes or "autopores" are crossed by well-developed horizontal "tabulæ," and are completely separated from one another by the smaller tubes or "siphonopores," which are also tabulate (fig. 214, C). Apart from their larger size, the autopores are further distinguished by the fact that they exhibit internally a variable number of longitudinal ridges which resemble the radiating "septa" of the Zoantharian corals. In the living *Heliopora cærulea* there are usually twelve of these radiating ridges in each autopore, but they can hardly be said to have any existence as definite structures, and appear rather to be formed by the projection into the cavity of the autopore of the prismatic siphonopores which bound the latter. In *H. Partschii*, of the Cretaceous rocks, the autopores possess from twenty-five to twenty-eight radial ridges which extend inwards to some distance, while *H. macrostoma*, of the same formation, has numerous septal ridges, but these are shorter. In any case these septal ridges not

only are not at all constant in number, but do not correspond with the mesenteries of the living polypes, these being always *eight* in number. Hence, the radial ridges of *Heliopora* must be regarded as "pseudosepta," and they are not homologous with the "septa" of the Madreporarians. The "siphonopores" or interstitial tubes are destitute of pseudosepta, and in the case of the living *H. cærulea* they are occupied by structures which Professor Moseley regards as

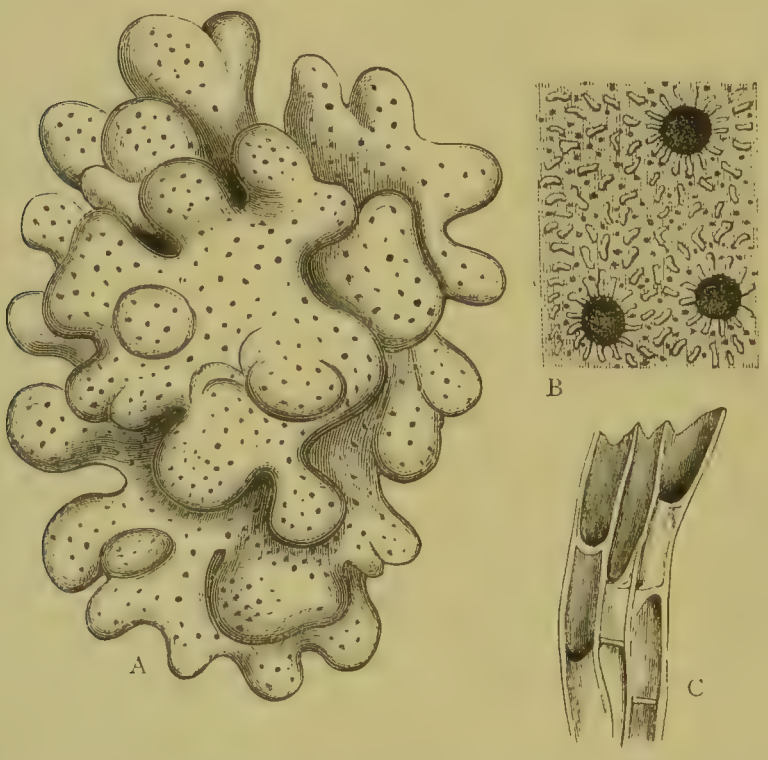


Fig. 214.—A, Colony of the recent *Heliopora cærulea*, of the natural size; B, Portion of the surface of the same, enlarged, showing the apertures of the larger and smaller zoöids; C, Vertical section of a few of the "siphonopores" enlarged, showing the tabulæ. (After Dana.)

probably of the nature of rudimentary, sexless polypes. These "siphonozoöids" have the form of sacs lined by the endoderm, closed externally, but communicating with the cavities of the autozoöids by means of canals in the soft tissues.

As regards its minute structure, the skeleton of *Heliopora* consists of fibro-crystalline carbonate of lime having a very peculiar and characteristic arrangement. When examined in thin sections (fig. 215), the corallum is seen to be composed of radially disposed, parallel, prismatic rods, the apices of which project above the general surface as prominent blunt papillæ which occupy the angles of junction of contiguous siphonopores, and constitute a diagnostic feature of

the genus *Heliopora*. The rods are generally placed, each, at the junction of four siphonopores, and are, therefore, essentially quadrilateral. They are firmly united with one another along their opposed sides by dentated sutures, and they are excavated along their angles by the siphonopores. Each rod possesses a single or multiple, generally elongated, apparently structureless axis, round which the calcareous tissue is disposed in radiating plates of great tenuity, which look in cross-sections (fig. 215, A) like fibres. The peculiar prismatic rods just described may be regarded as modified spicules, which become laterally anchylosed. In the fossil species of

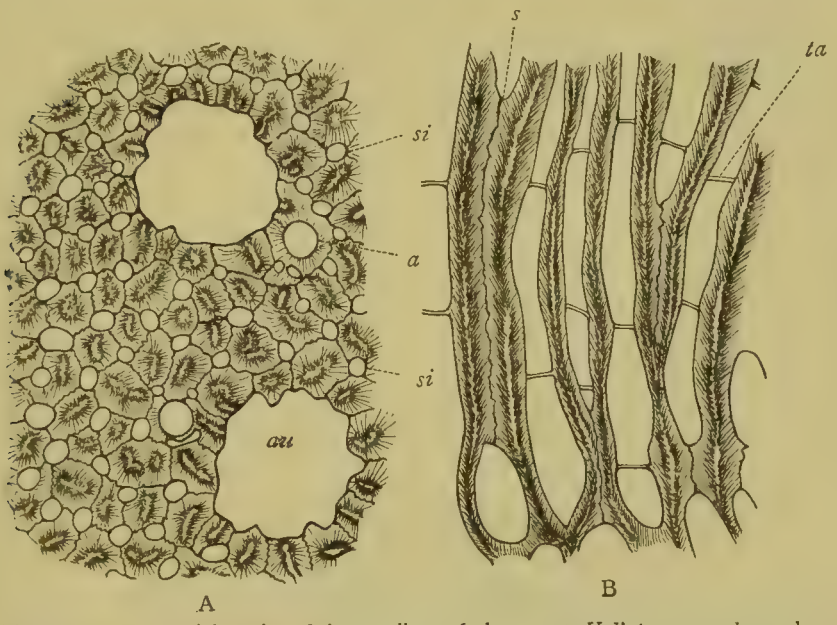


Fig 215.—A, Tangential section of the corallum of the recent *Heliopora cærulea*, enlarged twenty times; B, Longitudinal section, similarly enlarged. *au*, Autopore; *si*, Siphonopore; *a*, Tube of a parasitic Annelide (*Leucodora*); *s*, Suture between two adjoining spicules; *ta*, Tabula. (Original.)

Heliopora the skeletal structure is commonly largely affected by mineralisation, but in some cases (*e.g.*, in *H. Blainvilleana*) the minute structure of the corallum can be shown to be essentially similar to that of the recent *H. cærulea*. Even where obliterated by crystallisation, the minute structure can be inferred to have been spicular, as the surface always shows the characteristic projecting papillæ formed by the free ends of the skeletal rods.

It is worth noting in connection with the skeleton of *Heliopora* that the corallum in the recent *H. cærulea* is commonly traversed by numerous Annelide-tubes belonging to a species of *Leucodora*. These tubes are intermediate in size between the autopores and siphonopores (fig. 215, A), are very regularly distributed, and have their mouths flush with the general surface; while they are not mere borings, but are coated by

a layer of the coral-substance. For these reasons they have all the aspect of belonging to the corallum itself, and if they occurred in the fossil species of the genus their real nature might very readily be mistaken.

The mode of growth of the corallum in *Heliopora* is peculiar. The siphonopores appear to increase by means of "intermural gemmation," and not, as in the *Heliolitidæ* generally, by fission. On the other hand, the autopores, as can readily be observed in the growing ends of the colony, are produced by what von Koch has called "cœnenchymal gemmation." In this process—which will be spoken of again in connection with *Heliolites*—new autopores are produced by the apparent fusion and coalescence of a number of the siphonopores. According to Moseley's observations on the recent *H. cærulea*, this is effected by an arrest of growth of one or more of a group of siphonopores set apart for the production of a fresh autopore. "The arrested cell or cells form a central floor to the new calicle, around which lies a circular zone of contiguous, deeper, and older cells. The inner walls of these cells—*i.e.*, those nearer to the centre of the growing calicle—cease to grow, whilst their outer ones continue to develop, and being fused together form the lateral walls of the calicle. The plications in the wall of the fully formed calicle are to a great extent the result of this peculiar mode of growth." The conversion of a group of imperfect polypes into a single complete polype is doubtless a sufficiently remarkable phenomenon; but it is probable that, in reality, it is only a single siphonozoöid which ultimately becomes developed into an autozoöid, the remainder of the siphonozoöids concerned in the process becoming aborted. An analogous phenomenon has been observed by von Koch ('Zoologischer Anzeiger,' 1881) in the case of certain of the *Pennatulidæ*, in which the siphonozoöids become converted into autozoöids. The subject is one of great palæontological importance, since the same phenomenon—as will be subsequently shown—is observed in *Heliolites* and its allies; and it has been contended by Lindström that this fact is seriously opposed to the view that the interstitial tubes of *Heliolites* are of the nature of "siphonopores" rather than of "cœnenchymal tubes." The observations of Moseley upon *Heliopora cærulea* and of von Koch on the *Pennatulidæ* deprive this contention, however, of the weight which might otherwise be attached to it.

Since the researches of Moseley upon *Heliopora cærulea*, it has been usual to include *Heliolites* and its allies in the family of the *Helioporidæ*. The latter, however, possess a skeleton widely different from that of *Heliopora* in its minute structure, while the autopores are provided with an approximately constant number of septa, the nature of which appears to be different from that of the pseudo-

septa of *Heliopora*. For these reasons, amongst others, *Heliolites* and its relations may be placed, provisionally at any rate, in a separate family.

The recent *Heliopora cærulea* is found in the Indian and Pacific oceans, and fossil species of the genus are found in the Cretaceous and Eocene deposits. The imperfectly known genus *Polytremacis*, from the Cretaceous rocks, appears to be closely related to *Heliopora*.

HELIOLITIDÆ.

This family comprises a number of Palæozoic corals, of which the type is the widely distributed and abundant genus *Heliolites* itself, and is closely similar to the preceding group in its general characters. The corallum (fig. 216) is composite, and consists of two sets of tubes, of different sizes, of which the larger ("autopores") are, as a rule, completely separated from one another by the intervention of the smaller ("siphonopores"). Both sets of tubes are provided with tabulæ (fig. 216, c), and the autopores are furnished with lamellar, or rarely spiniform, septa, the number of which is almost invariably twelve in each corallite. In some cases the septa unite centrally to form a reticulate pseudocolumella. The siphonopores increase principally by fission, though partly by intermural gemmation, while the autopores are produced by

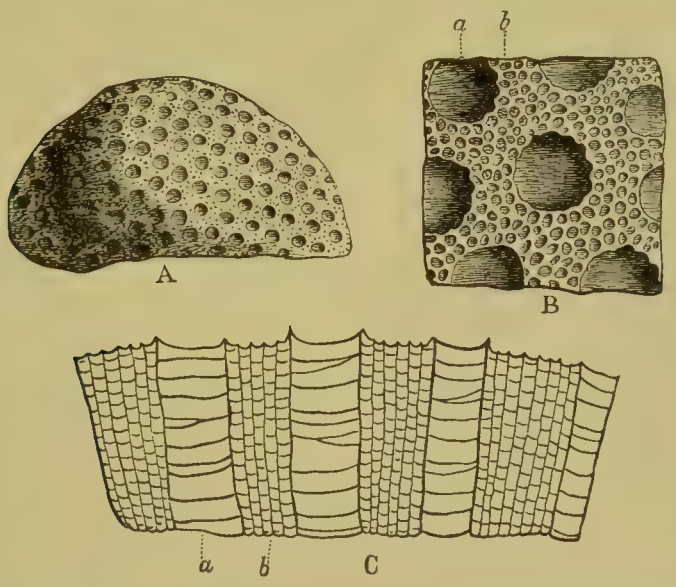


Fig. 216.—A, Small colony of *Heliolites interstinctus*, Linn., of the natural size; B, Small portion of the surface of the same, magnified, showing the autopores (*a*) and the mouths of the siphonopores (*b*); C, Vertical section of the same, enlarged, showing the tabulate autopores (*a*), and the similarly tabulate siphonopores (*b*). (Original.)

"cœnenchymal gemmation." The structure of the skeleton is not spicular.

As regards the minute characters of the skeleton, the autopores and siphonopores are *thin-walled*, and no traces of the peculiar prismatic rods of the corallum of *Heliopora* can be detected. The siphonopores are generally so largely developed as to form a complete zone, of one or more rows, of small tubes between adjacent autopores (fig. 216, B); but in *Heliolites dubius* (fig. 217, A) the number of the siphonopores is much reduced, and contiguous autopores are largely in contact. Both sets of tubes are furnished with

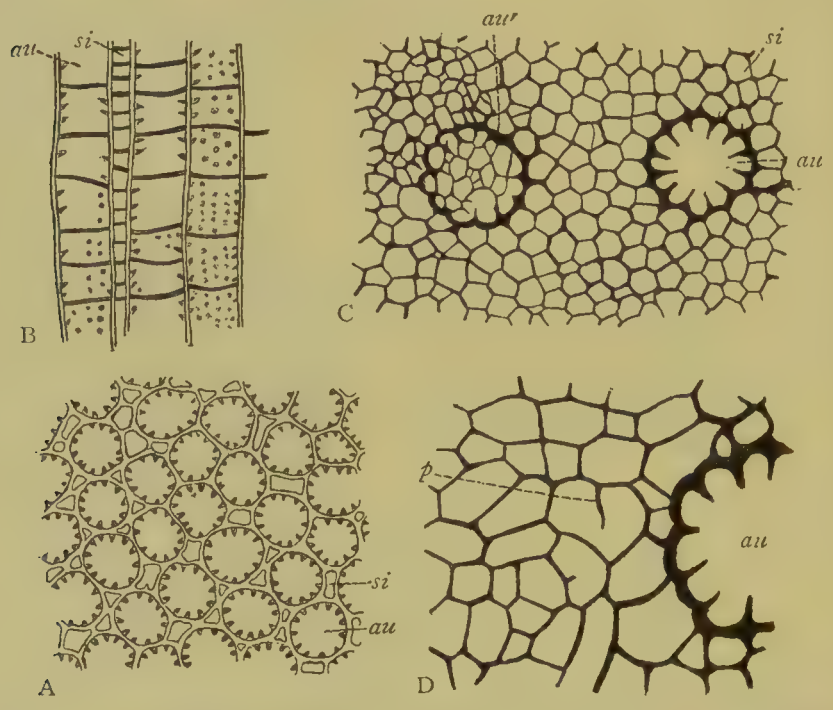


Fig. 217.—A, Cross-section of *Heliolites dubius*, from the Ordovician rocks of Esthonia, enlarged ten times; B, Vertical section of the same, similarly enlarged, showing the spiniform septa; C, Tangential section of *Heliolites porosus*, from the Middle Devonian of Büchel, showing "cœnenchymal gemmation," enlarged ten times; D, Part of another cross-section of the same, enlarged about twenty times, showing fission of the siphonopores. *si*, Siphonopores; *au*, Autopores; *au'*, Autopore being developed by "cœnenchymal gemmation"; *p*, Incomplete septum in a siphonopore, indicating partially accomplished fission of the tube. (Original.)

tabulæ, which are more numerous in the siphonopores than in the autopores (fig. 216, C). The siphonopores are without septa, but the autopores possess septal ridges or spines, which are very variable in their development, but are almost always twelve in number in each autopore. In some species (*Heliolites interstinctus*, *H. Murchisoni*, &c.) the septa are lamellar, but are rudimentary, and may even be represented only by slight bendings of the walls of the autopores. In other species (*H. porosus*, *H. parvistella*, &c.) the septa

are lamellar, and extend to a considerable distance into the interior of the visceral chamber, sometimes meeting to form a reticulated pseudocolumella (*H. intricatus*), or even showing alternate large and small septa (as in some examples of *Heliolites porosus*). Lastly, the septa may be in the form of twelve longitudinal rows of spines (as in *Heliolites dubius*, fig. 217, A and B, and in the true *Heliolites megastoma* of M'Coy).

As regards the mode of growth of the corallum in *Heliolites* and its allies, the siphonopores are usually developed fissiparously (fig. 217, D), though intermural gemmation also occurs. On the other hand, the autopores are produced by "cœnenchymal gemmation," in a fashion essentially similar to that which has been already described as occurring in *Heliopora*. In *Heliolites dubius*, in which the siphonopores are reduced to a minimum (fig. 217, A and B), a single siphonopore may sometimes be observed to be developed vertically and directly into an autopore. More usually, an autopore is produced by the arrested development of a group of siphonopores (as in *Heliopora*); and the process can be observed readily both in transverse and longitudinal sections. In the former (fig. 217, C) the enclosure of a group of siphonopores within an external wall, and the gradual development of the septa can be readily made out; while in long sections a few of the siphonopores are seen to be suddenly arrested in their growth, and commonly to be cut off by a common tabula, their place vertically being taken by a single autopore.

As regards their zoological position, the *Heliolitidæ* show points of relationship on the one hand to the *Alcyonaria*, and on the other hand to the *Zoantharia*. In the general features of the corallum (apart from the minute structure of the skeleton) the members of this family show a striking resemblance to the unquestionably Alcyonarian genus *Heliopora*, and in both groups we find the singular phenomenon of "cœnenchymal gemmation." This remarkable mode of increase, however, occurs also in the family of the *Fistuliporidæ;* so that undue weight must not be assigned to this alone. On the other hand, in the fact that the number of the septa is almost constantly twelve, while these structures are sometimes alternately long and short, and are occasionally in the form of rows of spines, we have a decided approach to various groups of the *Zoantharia*. The small tubes of the corallum of the *Heliolitidæ* have commonly been regarded as *cœnenchymal* in their nature, but Moseley's observations on *Heliopora* would strongly support the view here taken, that these structures are really tenanted by rudimentary polypes ("siphonozoöids"), and that the corallum is therefore really dimorphic. It has been already pointed out that the fact that the large corallites are formed by an arrested development and appa-

rent coalescence of a number of the small tubes does not really militate against the view that the latter are of the nature of "siphonopores."

As regards their *distribution in time*, all the members of the *Heliolitidæ* are Palæozoic, and all are confined to the Ordovician, Silurian, and Devonian periods.

The type-genus of the *Heliolitidæ* is *Heliolites* itself, in which the corallum is massive or branched, and the siphonopores are polygonal, and usually regular in form, and possess complete walls (figs. 216, 217). The species of *Heliolites* range from the Ordovician to the Devonian, and are very abundant in the Silurian rocks proper.

In the genus *Plasmopora* (fig. 218) the corallum is like that of *Heliolites* in general structure and appearance, but the walls of the

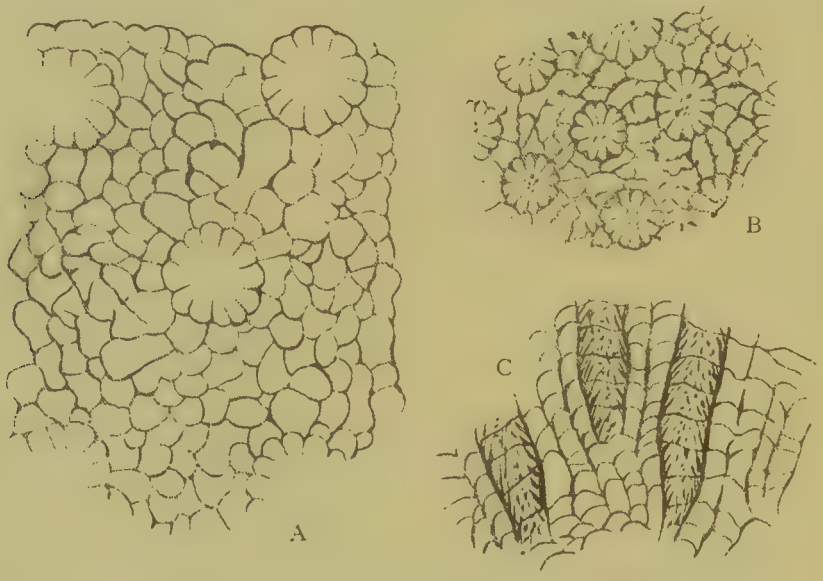


Fig. 218.—A, Transverse section of a specimen of *Plasmopora petaliformis*, Lonsd., from the Wenlock Limestone of Gotland, enlarged five times; B, Transverse section of *Plasmopora scita*, E. and H., from the Wenlock Limestone of Gotland, enlarged five times; C, Vertical section of the same specimen, similarly enlarged. (Original.)

siphonopores are incomplete or obsolete, and their tabulæ are thus enabled more or less largely to coalesce, and give rise to a vesicular tissue of lenticular cells (fig. 218). There are generally from two to five rows of siphonopores between adjoining autopores, and the septa may be either lamellar or spinulose. The species of *Plasmopora* are principally found in the Ordovician and Silurian rocks, but Devonian forms are also known. The Silurian deposits also contain various corals closely related to *Plasmopora*, for which the names of *Propora* and *Pinacopora* have been proposed, but these titles cannot be considered as of more than sub-generic value. In both these groups the siphonopores are much reduced in number, and the autopores are correspondingly close-set; the calices of the autopores being elevated above the general surface in *Propora*, but flush with the surface in *Pinacopora*, and the corallum in the latter being typically discoid in form.

HALYSITIDÆ.

This family comprises only the familiar Ordovician and Silurian corals known commonly as "Chain-corals," and constituting the single genus *Halysites*. The corallum in *Halysites* (fig. 219) is fasciculate and reticulate, composed of long, tubular, cylindrical corallites, which are placed side by side in intersecting and anastomosing laminæ or lines, any given corallite being united with its neighbours to the right and left along its whole length, and each lamina of the corallum consisting of no more than a single linear series of tubes. Each tube is enclosed in a strong imperforate wall, surrounded on its free sides by a thick epitheca; and there may be a distinct division of the corallites into two series of different sizes, in which case a single small tube is placed between each pair of the larger tubes. In other cases all the tubes are similar in size and structure. Septa may be wanting, and, when present, have the form of vertically disposed rows of spines, in cycles of twelve. The tabulæ are complete, horizontal, or slightly concave, not vesicular, the smaller corallites (when present) being much more closely tabulate than the larger ones.

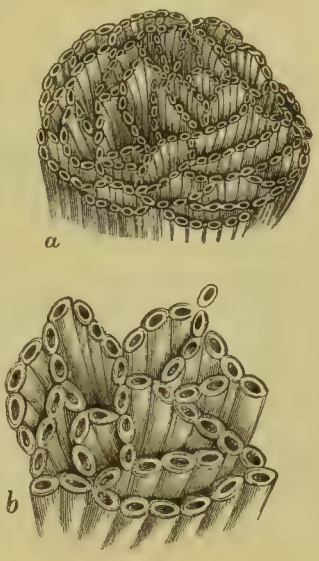


Fig. 219.—*a*, Upper surface of a fragment of *Halysites escharoides*, from the Silurian rocks of Canada, of the natural size; *b*, Part of the same enlarged. (Original.)

The species of *Halysites* may be divided into two groups, according as the corallum is composed throughout of corallites of one size, or consists of two sets of corallites of different sizes. The common *H. escharoides* of the Silurian rocks (fig. 219, and fig. 220, A) is an example of the forms in which all the corallites are similar. On the other hand, in the familiar *H. catenularia* of the same formation, the corallum consists of large corallites separated by the intervention of small, closely tabulate tubes (fig. 220, B and C). Septa are sometimes absent (fig. 220, B), but in other instances they are well developed (fig. 220, A). When present, the septa always have the form of vertical rows of spines, twelve of such rows being usually recognisable in each corallite. The mode of growth of the corallum is by "stolonal gemmation," the colony in its early condition being not unlike that of an *Aulopora*.

The zoological position of the genus *Halysites* cannot be regarded as certain, but it would appear, on the whole, to be most nearly

related to the *Heliolitidæ*. At the same time, there are indications of a possible relationship between *Halysites* and the *Syringoporidæ*. This is particularly shown by the peculiar coral described by Mr Etheridge from the Arctic Silurian rocks under the name of *Halysites catenulatus*, var. *Feildeni*, which has the *form* of *Halysites*, but

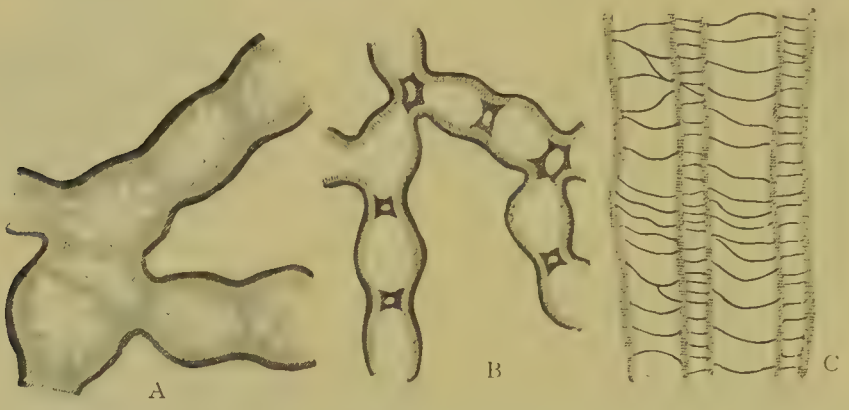


Fig. 220.—A, Transverse section of *Halysites escharoides*, Lam., from the Silurian of Gotland, enlarged ten times, showing the spiniform septa, and the absence of a series of small corallites; B, Transverse section of *Halysites catenularia*, Linn., from the Wenlock Limestone of Dudley, enlarged five times, showing the absence of septa, and the presence of a series of small corallites; C, Vertical section of a few corallites of the last specimen, enlarged five times, showing the large and small corallites, and the difference in the tabulation of these. (Original.)

in which the corallites resemble those of *Syringopora* in being furnished with connecting-tubes. This singular type cannot, however, be regarded as properly belonging to *Halysites*.

Tetradiidæ.

This small family includes only the single genus *Tetradium*, which, so far, has only been detected in the Ordovician rocks of North America. In this genus the corallum (fig. 221) is massive, and is composed of long, prismatic and closely contiguous corallites, which are of small size, and have imperforate walls. The tubes are furnished with longitudinal inflections or plications, generally four in number in each tube, which do not reach the centre of the visceral chamber, and which give a characteristic cruciform or petaloid aspect to cross-sections of the corallites (fig. 221, B). These longitudinal plications are apparently to be regarded as of the nature of septa or pseudosepta. The tubes are crossed by numerous tabulæ (fig. 221, C), which are sometimes complete, but are at other times perforated by central apertures (as in the tabulæ of some species of *Stenopora*). The mode of increase appears to be by fission.

Tetradium appears to be related to *Halysites*, but its true affinities and zoological position are uncertain.

CHÆTETIDÆ.

This family includes only the single genus *Chætetes*, all the known species of which are found in the Carboniferous rocks, though vari-

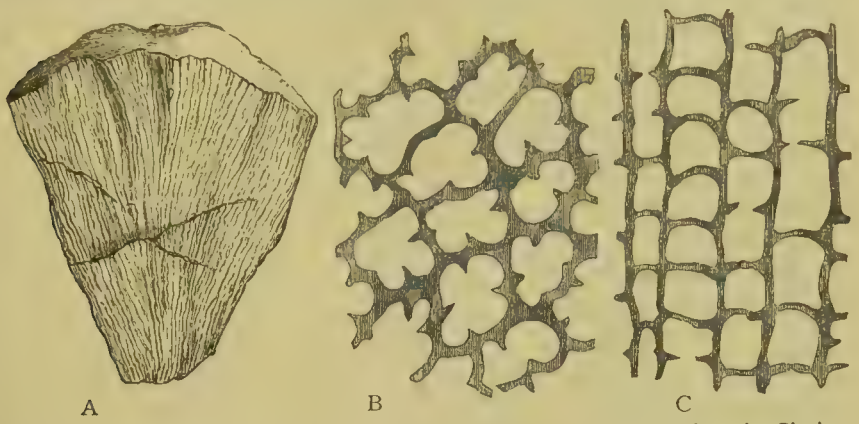


Fig. 221.—A, Fragment of a large corallum of *Tetradium minus*, Safford, from the Cincinnati Group of North America, of the natural size; B, Transverse section of the same, enlarged ten times, showing the petaloid form of the tubes and the short septa; C, Vertical section of the same, similarly enlarged, showing the tabulæ. (Original.)

ous Monticuliporoids have been formerly referred to the same genus. The type-species is the *C. radians* of the Carboniferous Limestone

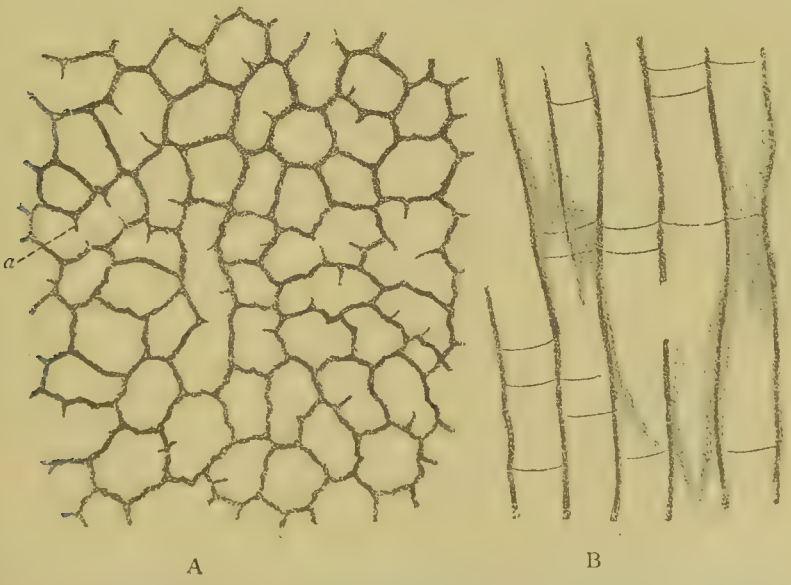


Fig. 222.—A, Tangential section of *Chætetes Etheridgii*, from the Carboniferous Limestone of Westmorland, enlarged about ten times; B, Longitudinal section of the same, similarly enlarged. *a*, Imperfect longitudinal partition produced by uncompleted fission of an old corallite. (Original.)

of Russia, but the characters of all the known species are essentially the same. The corallum in *Chætetes* is massive or laminar, often

of large size; and consists of long, tubular, prismatic corallites, which are not only in close contact throughout, but are so completely incorporated by fusion of their walls that rough fractures almost always expose the interior of the tubes. The corallites are all of one kind, are irregularly polygonal, and possess completely imperforate walls. The tubes are traversed by a few complete tabulæ (fig. 222, B), which are commonly developed periodically at successive levels; but there are no septa. The increase of the corallum is by fission of the old tubes; and hence in cross-sections (fig. 222, A) it is common to observe imperfect longitudinal partitions projecting into the visceral chambers of the corallites, and indicating the uncompleted fission of the tubes.

The zoological affinities of the genus *Chætetes* are quite uncertain, and it is not even clear that it is referable to the *Alcyonaria*. Many authorities regard the genus as belonging to the *Polyzoa* rather than to the *Cœlenterata;* but the fissiparous mode of its development, and the total absence of pores or canals connecting adjoining tubes, would militate strongly against its being referred to the former group.

Auloporidæ.

This small and imperfectly understood group comprises the Palæozoic genera *Aulopora*, *Cladochonus* (*Pyrgia*), and *Monilipora*, of which the first may be taken as the type. The corallum in *Aulopora* (fig. 223, A) has the form of a creeping, branched, or reticulate system of tubes, attached by the whole of the lower surface to the exterior of a shell, coral, or other foreign body. The prostrate stems or stolons send up at longer or shorter intervals reclined tubular or trumpet-shaped corallites, which are free terminally, and do not grow up to form a fasciculate mass. As regards their internal structure, the corallites are commonly furnished with curved or horizontal tabulæ, and rudimentary septa are present in the form of marginal striæ or rows of tubercles. The walls of the corallites are imperforate, and the mode of increase of the corallum is by stolonal gemmation. The species of *Aulopora* range from the Ordovician to the Carboniferous inclusive.

Cladochonus (*Pyrgia*) closely resembles *Aulopora*, but the colony is only attached to foreign bodies by isolated points of attachment, and grows in an erect manner rather than as a creeping network. In its young state, the corallum consists of a single trumpet-shaped corallite (fig. 223, C and D), attached by processes springing from its lower surface. *Monilopora* possesses an Auloporoid corallum, which is attached parasitically to the stems of Crinoids in a ring-like manner, the walls of the trumpet-shaped corallites having a peculiar

cancellated structure. Both these genera are confined to the Carboniferous period.

The true relationships of the *Auloporidæ* are uncertain. A close resemblance exists between the adult colonies of *Aulopora* and the young stages of both *Syringopora* and *Halysites*, but it is questionable

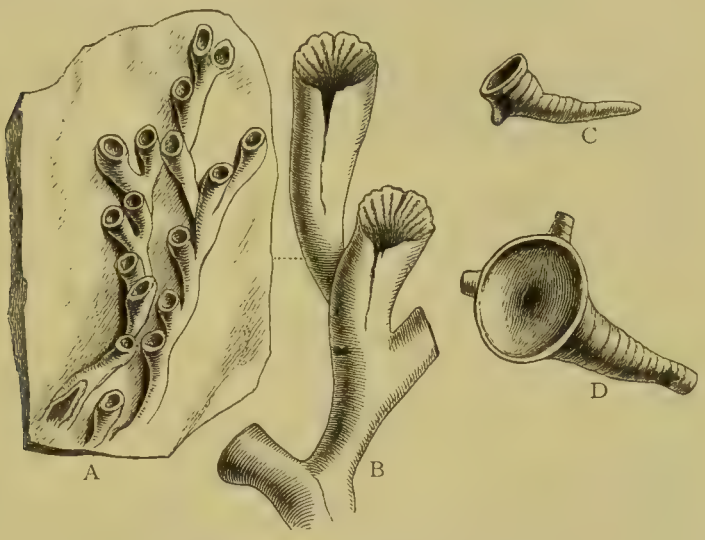


Fig. 223.—A, Portion of *Aulopora tubæformis*, of the natural size; and B, Portion of the same, enlarged (after Goldfuss). Devonian. C and D, *Cladochonus* (*Pyrgia*) *Michelini*, of the natural size, and enlarged (after Milne-Edwards and Haime). Carboniferous.

if this likeness bespeaks any real affinity to either of these genera. In the stolonal method of gemmation characteristic of the Auloporoids we have a marked Alcyonarian feature, and the group may therefore be provisionally placed in the division of the *Alcyonaria*.

LITERATURE OF ACTINOZOA.

1. "Manuel d'Actinologie et de Zoophytologie." De Blainville. 1834-37.
2. "Histoire des Animaux sans Vertèbres," vol. ii. Lamarck. (Ed. 2, 1836.)
3. "Histoire Naturelle des Coralliaires ou Polypes proprement dits." Milne-Edwards and Haime. 1855-60.
4. "Recherches sur les Polypiers." 'Ann. des Sciences Nat.' Milne-Edwards and Haime. 1848-52.
5. "Iconographie Zoophytologique." Michelin. 1840-47.
6. "Beiträge zur physiologischen Kenntniss der Korallenthiere im Allgemeinen und besonders des rothen Meeres." 'Abhandl. d. Berl. Akad.' Ehrenberg. 1832.
7. "Zoophytes." 'Report of the Exploring Expedition under Captain Wilkes.' Dana. 1848.
8. "Die Korallthiere des rothen Meeres." Klunzinger. 1877-79.

9. "Die Bindesubstanz der Cœlenteraten." 'Icones Histiologicæ.' Kölliker. 1866.
10. "A Revision of the Families and Genera of the Sclerodermic Zoantharia or Madreporaria." 'Journ. Linn. Soc. (Zool.),' vol. xviii. Martin Duncan. 1884.
11. "Report on the Reef Corals." 'Challenger Reports,' vol. xvi. Quelch. 1886.
12. "On the Helioporidæ and their Allies." 'Challenger Reports,' vol. ii. Moseley. 1881.
13. "On the Anatomy of Mussa and Euphyllia and the Morphology of the Madreporarian Skeleton." 'Quart. Journ. Micro. Sci.,' vol. xxviii. Bourne. 1887.
14. "Das Skelet der Alcyonarien." 'Morphologisches Jahrbuch.' Von Koch. 1878.
15. "Die Gorgoniden des Golfes von Neapel." Von Koch. 1887.
16. "Die ungeschlechtliche Vermehrung (Theilung und Knospung) einiger palæozoischen Korallen." 'Palæontographica.' Neue Folge, ix. Von Koch. 1883.
17. "Beiträge zur Kenntniss fossiler Korallen." 'Zeitschr. d. deutschen Geolog. Gesellschaft,' Jahrg. 1869-70. Kunth.
18. "Introduction à l'étude des Polypiers Fossiles." Fromentel. 1858-61.
19. "Handbuch der Palæontologie." Bd. i. Lief. 2. Von Zittel. 1879.
20. "Polypiers Fossiles des Terrains Paléozoiques." Milne-Edwards and Haime. 1851.
21. "Monograph of the British Fossil Corals." 'Palæontographical Society.' Milne-Edwards and Haime. 1851-54.
22. "British Fossil Corals." (Supplement to the preceding.) 'Palæontographical Society.' Martin Duncan. 1865-72.
23. "Lethæa Palæozoica." Lief. 2. Ferdinand Roemer. 1883.
24. "Monographie der Sclerodermata Rugosa aus der Silur-formation Estlands," &c. Dybowski. 1873.
25. "Reports on the British Fossil Corals." 'Rep. Brit. Assoc.,' 1869-71. Martin Duncan.
26. "On the Affinities of the Palæozoic Tabulate Corals with Existing Species." 'Amer. Journ. Sci. and Art,' 1872. Verrill.
27. "Affinities of the Anthozoa Tabulata." 'Ann. of Nat. Hist.' ser. 4, vol. xviii. 1876. Lindström.
28. "On the Structure and Affinities of the Palæozoic Corals of the Palæozoic Period." Nicholson. 1879.
29. "Monograph of the Girvan Silurian Fossils." Nicholson and Etheridge, jun. 1878-80.
30. "Die Korallen der Nattheimer Schichten." 'Palæontographica,' vol. xxi. Becker and Milaschewitsch. 1875.
31. "Petrefaktenkunde Deutschlands." (Korallen.) Quenstedt. 1881.
32. "Nouvelles Recherches sur les Animaux Fossiles du Terrain Carbonifère de la Belgique." Premiere Partie. 1872. De Koninck.
33. "Petrefacta Germaniæ." Goldfuss. 1826-33.
34. "British Palæozoic Fossils." M'Coy. 1851.
35. "Index to the Generic Names applied to the Corals of the Palæozoic Formations." 'Bihang till K. Svenska Vet-Akad. Handlingar.' Bd. viii. 1883. Lindström.
36. "Obersilurische Korallen von Tshau-Tien." (In Richthofen's 'China.') Lindström.

37. "Palæozoiska Formationernas Operkelbärande Koraller." (Operculate Corals of the Palæozoic Formations.) Lindström. 1882.
38. "Fossil Corals of the State of Michigan." Rominger. 1876.
39. "Die Cyathophylliden und Zaphrentiden des deutschen Mitteldevon." Frech. 1886.
40. "Die Korallenfauna des Oberdevons in Deutschland." 'Zeitschr. d. deutschen Geolog. Gesellschaft.' Jahrg. 1885. Frech.
41. "Ueber einige Anthozoen des Devon." 'Zeitschr. d. deutschen Geolog. Gesellschaft.' Jahrg. 1881. Schlüter.
42. "On the Genera Heterophyllia, Battersbyia, Palæocyclus, and Asterosmilia." 'Phil. Trans.,' 1867. Martin Duncan.
43. "Ueber die verwandschaftlichen Beziehung einiger Korallengattungen." 'Palæontographica.' Neue Folge, ix. 1883. Pratz.

CHAPTER XXI.

THE MONTICULIPOROIDS.

We may consider here the remarkable groups of organisms (*Monticuliporidæ* and *Fistuliporidæ*), which have been collectively spoken of as the "Monticuliporoids," and the precise systematic position of which is still uncertain. The Monticuliporoids, in fact, exhibit a combination of characters; and palæontologists have therefore, so far, come to no final decision as to the true relationships of these puzzling organisms, some authorities regarding them as a peculiar group of Corals, while others consider them to be referable to the *Polyzoa*.

The structural characters of the Monticuliporoids are very complex, and are for the most part only capable of complete elucidation by means of microscopic examination, while the number of different forms included in the group is very large. For these reasons, nothing more will be here attempted than to give a brief outline of the general morphology of the entire series, with the distinctive characters of the two families of the *Monticuliporidæ* and *Fistuliporidæ*, and a brief notice of the more important types included in these.

In all the Monticuliporoids, the skeleton is composed of closely approximated, prismatic or sub-circular tubes, sometimes all similar to one another, sometimes of different sizes, which are provided with distinct walls. In the centre of the colony the tubes are always thin-walled, more or less polygonal in shape, and similar to one another in internal structure; but as they approach the surface, they diverge from one another by the intercalation of new tubes, their walls commonly becoming at the same time thickened, and their internal characters being modified. It is in the outer, or "mature," region of the colony (fig. 224, E, *m*) that a second set of tubes is usually developed in those cases in which the colony is dimorphic. The exterior of the colony commonly exhibits at intervals definite areas ("monticules" and "maculæ"), which are elevated or depressed as regards the general surface, and consist of larger or smaller tubes

than the average (fig. 224, *mo*). The walls of the tubes are imperforate; tabulæ are always present; and true "septa" are probably always wanting, though "pseudosepta," in the form of radial plates or spines, are in rare cases developed.

The *form* of the skeleton in the Monticuliporoids is extremely variable, though it is in general tolerably constant for each species. In many forms the skeleton is dendroid or ramose (fig. 224, B), consisting of cylindrical or subcylindrical stems, which have a fixed base and branch more or less freely above, the entire surface being covered with the openings of the tubes. In others, the skeleton is so far modified from the preceding that it assumes the form of an erect, laminar or frondescent

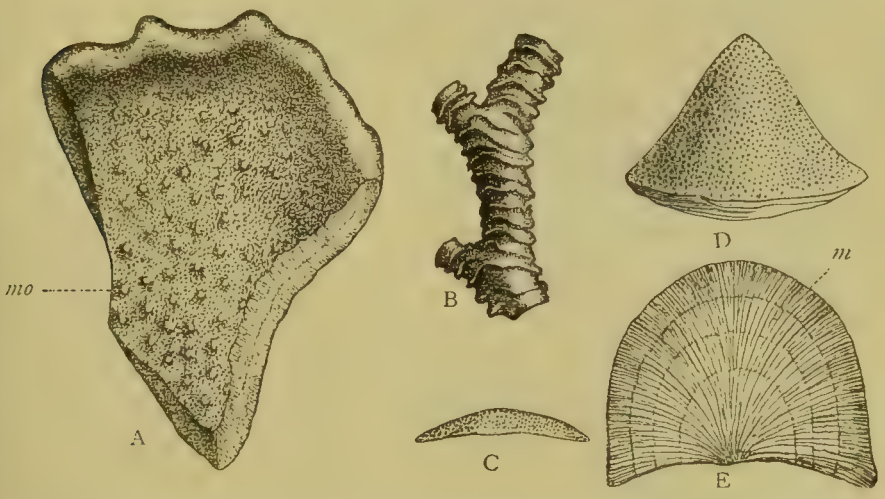


Fig. 224.—A, Fragment of the frondescent corallum of *Monticulipora mammulata*, D'Orb. (= *Peronopora molesta*, Nich.) showing "monticules" (*mo*); B, Fragment of the dendroid corallum of *Callopora?* (*Heterotrypa*) *rugosa*, E. and H.; C, Discoid corallum of *Amplexopora discoidea*, James; D, Hemispherical corallum of *Callopora nummiformis*, Dyb., viewed sideways; E, The same vertically fractured, showing the divergence of the tubes and the peripheral "mature" region (*m*). All the figures are of the natural size, except E, which is reduced. (Original.)

colony, composed of two strata of tubes the mouths of which open on the two sides of the expansion (fig. 224, A). In numerous other types (fig. 224, D) the colony is hemispherical, the usually flattened or concave base being covered with a concentrically wrinkled epitheca, while the mouths of the tubes cover the entire upper surface. In still other forms, the tubes are very short, and the colony has the form of a thin, flat or concave disc, with a striated basal plate (fig. 224, C). In other cases, the skeleton assumes a lobate or massive form; and in others it is encrusting, and is attached parasitically to foreign bodies.

A very important distinction between different types of the Monticuliporoids is based upon the homomorphic or heteromorphic condition of the colony. In some forms (viz., in *Monotrypa*) the tubes are essentially similar throughout the colony in size and internal structure, any difference which may be observed between different

tubes appearing to depend upon their relative age only. On the other hand, most Monticuliporoids exhibit a distinct dimorphism, the colony being composed of at least two kinds of tubes, which differ in size and in internal structure. The relative proportions of these two sets of tubes to one another vary in different forms, but the larger ones may be spoken of as "autopores," and the smaller ones as "mesopores." The "autopores" may be regarded as having lodged the perfect zoöids of the colony, and they are distinguished both by their comparatively large size (fig. 225, *a*), and also by the nature of their tabulæ, these structures being usually comparatively

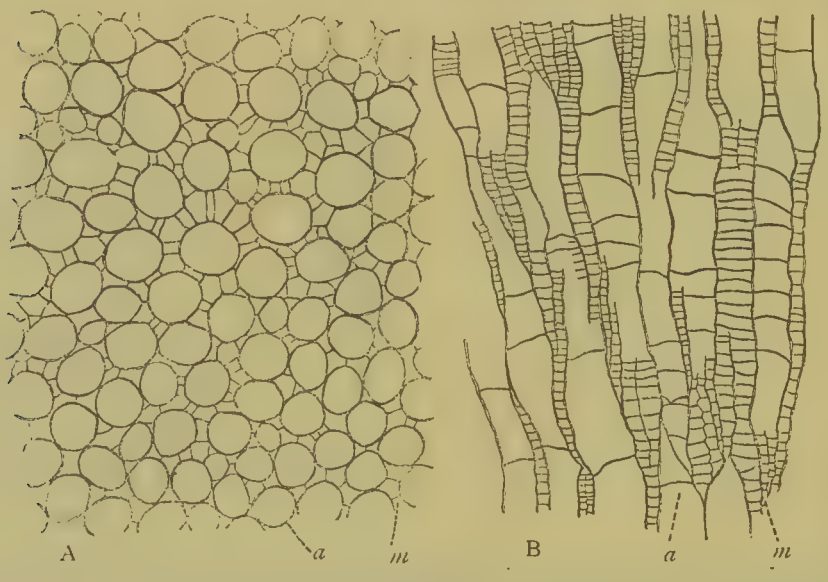


Fig. 225.—A, Tangential section of *Callopora nummiformis*, Dyb., from the Silurian rocks of Esthonia, enlarged twenty times; B, Vertical section of the same, similarly enlarged. *a*, Autopore; *m*, Mesopore. (Original.)

few and remote, or being specially modified in form. On the other hand, the "mesopores," or "interstitial tubes," occupy, in greater or less number, the spaces between the autopores, and are not only smaller than the latter, but are more closely tabulate (fig. 225, *m*). The mesopores have often been considered as merely of the nature of a "cœnenchymal" or "interstitial" tissue, but they may be regarded, with great probability, as really having lodged imperfect zoöids, and as corresponding with the "siphonopores" of the *Heliporidæ* and *Heliolitidæ*.

In addition to the preceding, many Monticuliporoids—whether otherwise homomorphic or heteromorphic—possess yet a further series of tubes, which have been spoken of as "acanthopores" or "spiniform corallites." These are minute cylindrical tubes, with thick and laminated walls (fig. 226), which run in the substance of

the walls bounding contiguous autopores or mesopores, and the free ends of which usually project above the general surface as spines or blunt tubercles (fig. 227). The "acanthopores," when present, are only developed in the peripheral or "mature" region of the colony; and they are readily recognised in tangential sections (fig. 226, *ac*), as round bodies which usually show a minute central tube surrounded by a thick and dark-coloured wall of laminated calcareous tissue. Waagen has expressed the opinion that the "acanthopores" are only immature tubes, but this is conclusively shown to be erroneous by the fact that, while immature tubes can be readily demonstrated in *all* specimens, the "acanthopores" are strictly confined to particular *species* of Monticuliporoids, and are uniformly absent in others.

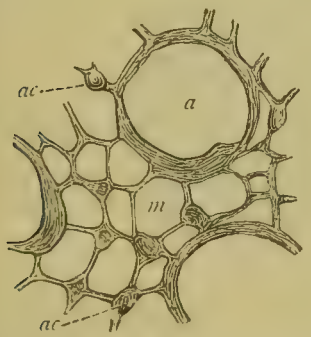


Fig. 226.—A few corallites of *Fistulipora eriensis*, Rom.: *a*, Autopores; *m*, Mesopores; *ac*, Acanthopores. Enlarged about forty times.

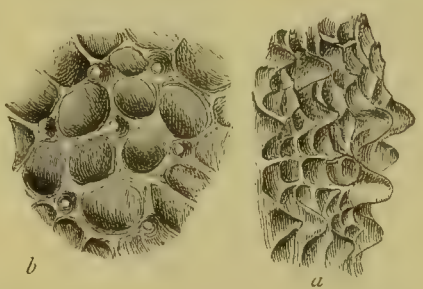


Fig. 227.—*a*, Profile view of a portion of the surface of *Dekayia aspera*, showing acanthopores; *b*, The same, viewed from above. Enlarged about forty times. (After Nicholson and Foord.)

Moreover, they differ entirely in structure from the young tubes, and unlike the corallites (whether young or old) they project above the general surface of the colony in the form of spines. Again, when they are limited in number, the acanthopores occupy definite positions as regards the ordinary tubes of the colony; and, finally, in many forms (fig. 230, D) the acanthopores are so numerous as to render the hypothesis that they are of the nature of young corallites quite untenable. It may, then, be taken as certain that the acanthopores represent a special morphological element in the Monticuliporoid colony; but it is difficult to give any satisfactory explanation as to their true nature. They may be regarded, with considerable probability, as of the nature of aborted zoöids; and possibly their nearest analogue is to be found in the "avicularia" of the recent *Polyzoa*. This suggestion is supported by the fact that in some living Polyzoans (as in *Retepora*) the avicularia are attached to thickened tubes immersed in the substance of the skeleton, the appearance of which in thin sections is very similar to that observed in sections of those Monticuliporoids which possess acanthopores.

In many Monticuliporoids the surface is studded at intervals with small elevations which are known as "monticules" (fig. 224, A), and which are usually constituted by groups of corallites of larger than the average size. In other cases, there are scattered depressed areas, usually stellate in form, which are occupied by the "mesopores" only, and which are known as "maculæ." These can be shown to be really of the nature of centres of growth for the colony.

So far as is certainly known, the walls of the tubes in the Monticuliporoids are wholly destitute of mural pores, or foramina of any kind, the chambers of contiguous tubes being thus completely separated from one another. Considering the vast number of thin

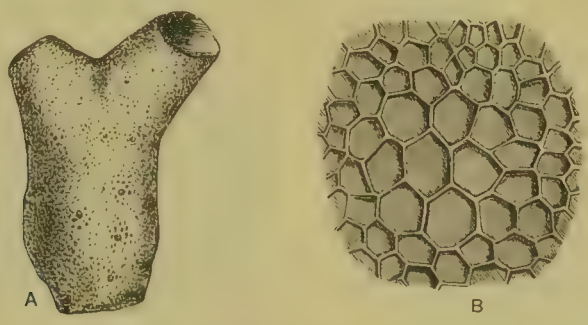


Fig. 228.—A, Part of a typical specimen of *Monotrypella pulchella*, E. and H., from the Wenlock Limestone of Dudley, of the natural size; B, Part of the surface of the same, embracing one of the clusters of large corallites, enlarged. (Original.)

sections of the Monticuliporoids which have been examined by competent observers, the imperforate condition of the walls of the tubes in the Monticuliporoids must be regarded as free from doubt; and it constitutes one of the most marked features by which these organisms are separated from the Cyclostomatous *Polyzoa*. Mural pores have been described by De Koninck, and also by the present writer and Mr R. Etheridge, jun., as occurring in the genus *Stenopora;* but the exhaustive investigations of Waagen and Wentzel have shown that even in this genus the walls are really imperforate, and that the structures described as pores in such forms as *Stenopora Jackii* must admit of a different interpretation. Mr Ulrich has also described pores as occurring in a Monticuliporoid, but it may be suggested with much probability that, in this case, the organism observed is really referable to some other group.

In almost all the Monticuliporoids the tubes are crossed by transverse calcareous partitions or "tabulæ," which are in general very numerous (fig. 225, B), though occasionally limited in their development. Usually, in the dimorphic forms, the autopores have few and remote tabulæ, while the mesopores have a much greater abundance of these structures. Mostly, the tabulæ are "complete," forming horizontal partitions which extend entirely across the tubes (fig.

225, B). In other cases, one half of the tube is crossed by straight tabulæ, while the other half is occupied by curved or "cystoid" tabulæ, forming a series of lenticular vesicles on one side (fig. 230, F). In other cases (*Prasopora*), "cystoid" tabulæ are developed all round the periphery of the tube, and the centre is occupied by straight tabulæ. Lastly, in *Fistulipora*, the walls of the mesopores are incompletely developed, and the tabulæ unite to form a tissue of lenticular vesicles between the autopores, the genus thus bearing the same relation, in this respect, to *Callopora* that *Plasmopora* does to *Heliolites* among the *Heliolitidæ*.

The great majority of the Monticuliporoids exhibit no radial structures in the tubes which could be compared with the "septa" of an ordinary coral. In a few forms, such structures do occur, but it is doubtful if in any such instance we have to deal with structures really developed in mesenteries, and therefore really homologous with the "septa" of the *Zoantharia*. Thus in *Fistulipora*, each autopore is provided with two longitudinal folds, situated opposite one another, towards one end of the visceral chamber. Again, in a hitherto undescribed species of *Callopora* (fig. 229, A) each

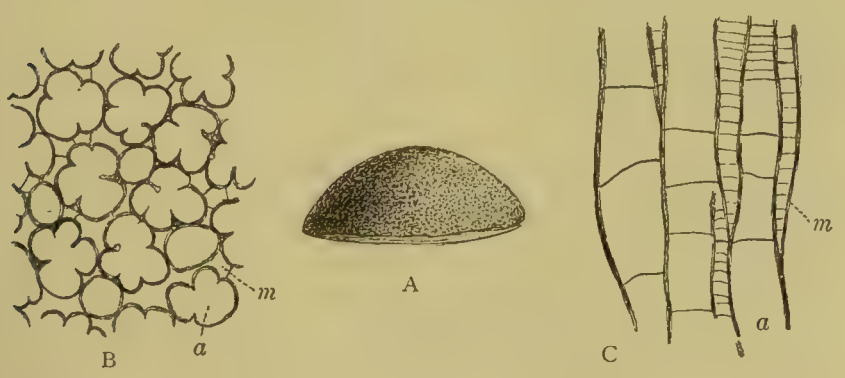


Fig. 229.—A, A large specimen of *Callopora Foordii*, of the natural size; B, Tangential section of the same, showing the pseudoseptal folds in the autopores, enlarged twenty times; C, Vertical section of the same, similarly enlarged. *a*, Autopores; *m*, Mesopores. From the Ordovician rocks of Esthonia. (Original.)

autopore is provided with from two to five radial plications of the wall, which closely resemble the "septa" of *Tetradium*, and give a characteristic floriform appearance to cross-sections of the corallites. Moreover, in typical examples of *Monticulipora mammulata*, D'Orb. (= *Peronopora molesta*, Nich.), the author has detected radially disposed spines (fig. 230, D), which have much the appearance of the radial spines of *Favosites* and *Syringopora*; and similar structures have been recognised by other observers in other forms.

Lastly, as regards the *mode of growth* of the skeleton, new tubes are most usually produced by "intermural gemmation," in a manner

precisely similar to that which obtains in the *Favositidæ*. It is for this reason that rough fractures of the Monticuliporoids expose the *walls* of tubes, whereas in the genus *Chætetes*, where the growth is fissiparous, fractures usually lay open the visceral chambers of the corallites. It is, however, interesting to note that *fission* also occurs not rarely in the Monticuliporoids, though it is not so common a mode of increase as gemmation. In the mesopores of *Fistulipora* and some allied types fission seems to be the ordinary mode of increase, as it is in the case of the siphonopores of the *Heliolitidæ*. This fact would go far to prove that the mesopores are not merely cœnenchymal; since fission can hardly occur unless we suppose the existence of separate zoöids endowed with the power of division. The occurrence of fission in the autopores of the Monticuliporoids is also strongly against the reference of these organisms to the Cyclostomatous *Polyzoa*, since these latter invariably increase by means of gemmation. A still more interesting fact is the occurrence—as described by Waagen—of "cœnenchymal gemmation" among the Fistuliporoids, autopores in these cases being formed by the abortion and apparent fusion of a group of mesopores, in a manner precisely similar to that previously noted as occurring in *Heliopora* and *Heliolites*. This fact would also bear very strongly against the view that the Monticuliporoids are to be regarded as belonging to the *Polyzoa*.

It must be admitted, however, that the *zoological affinities* of the Monticuliporoids are still a matter of uncertainty. In many of their features, both structural and developmental, they show marked relationships with the *Actinozoa* generally, and with the *Alcyonaria* in particular, while in others they approach the *Polyzoa;* and it must, in the meanwhile, remain a matter of individual opinion whether the Monticuliporoids should be regarded as a very peculiar group of Corals or as an equally peculiar group of Polyzoans. It would be out of place here to enter into any detailed discussion of a question so complex, but it may be of advantage to summarise briefly the chief points which must be taken into consideration in coming to any decision as to the systematic position of the Monticuliporoids.

Leaving the *external form* of the skeleton entirely out of consideration, the *general* features which favour the reference of the Monticuliporoids to the *Cœlenterata* are the following:—

1. The common dimorphism of the colony in the Monticuliporoids finds its best parallel in *Heliopora* and *Heliolites*, the Cœlenterate nature of which is undoubted. In particular, the structural relationships between *Fistulipora* and *Heliolites*, or *Plasmopora*, are exceedingly close; the skeleton consisting in both of large, sparsely tabulate tubes ("autopores") separated by smaller, closely tabulate tubes ("mesopores" or "siphonopores"), and the former of these possessing radial structures of the nature of "septa" or "pseudosepta."

2. The Monticuliporoids increase by fission as well as by gemmation, whereas the recent *Polyzoa* appear to be uniformly characterised by a gemmiparous mode of development, which varies in its precise details in different groups. Moreover, the gemmation of the Monticuliporoids is "intermural," and is precisely similar to that which obtains among the *Favositidæ*.

3. "Cœnenchymal gemmation" occurs in the *Fistuliporidæ*, this mode of increase being otherwise absolutely characteristic of *Heliopora* and of the *Heliolitidæ*.

4. The walls of the tubes in the Monticuliporoids are imperforate; whereas in the calcareous *Polyzoa* the skeleton seems to be almost always (probably always) porous, and the cavities of contiguous cells are usually placed in direct communication by means of connecting-foramina or tubes.

5. The abundant development of "tabulæ" in the Monticuliporoids is a feature in which these organisms resemble a large number of undoubted Corals.

6. Certain Monticuliporoids possess in their autopores radial folds or plications which may be compared with the "pseudosepta" of *Heliopora;* while others (*Monticulipora mammulata*) possess radially disposed calcareous spines, which are closely similar to the septal spines of *Favosites*, of *Syringopora*, and of certain species of *Heliolites*.

On the other hand, there are the following considerations which would point to a relationship between the Monticuliporoids and the *Polyzoa*, or which, at any rate, would more or less diminish the importance of some of the features above mentioned as showing the Cœlenterate affinities of these organisms.

1. The polyzoary of *Heteropora* (which is undoubtedly a Polyzoan) consists of large tubes scattered among smaller ones, though there does not appear to be any essential difference in the *structure* of these respectively.

2. "Tabulæ" are by no means confined to the Cœlenterates, precisely similar structures—so far as appearance goes—being present in undoubted *Polyzoa* (*e.g.*, in *Heteropora*, *Domopora*, *Fascicularia*, *Alveolaria*, &c.)

3. Radial structures in the form of rows of spines are present in a number of *Polyzoa* (*e.g.*, in *Heteropora*, *Discoporella*, &c.)

4. There are various *Polyzoa* (such as *Rhombopora Hamiltonensis*, *Ceriopora interporosa*, and some of the Fenestellids) which possess structures apparently very similar to the "acanthopores" of many Monticuliporoids. Structures presenting in some respects the same aspect are found in the recent *Reteporæ*, in which they serve to carry the avicularia.

5. Portions of the skeleton of *Fistulipora incrustans*, Phill., have been shown by John Young to become thickened, and to exhibit a finely tubulated structure similar to that seen in the skeleton of the *Fenestellidæ*.

6. According to the observations of Lindström, certain of the Monticuliporoids pass through early stages of development in which the skeleton is of a distinctly Polyzoan type. As an example of this, we may take the singular *Callopora heterosolen*, the basal (and therefore first-formed) portion of which exhibits Polyzoan characters, while the main mass of the skeleton is of the ordinary Monticuliporoid type.

7. Lastly, certain extinct forms the Polyzoan nature of which seems unquestionable are hardly distinguishable, as regards minute structure, from other forms which have always been regarded as Monticuliporoids. Thus, an extremely close structural resemblance obtains between *Ceriopora interporosa*, on the one hand, and *Batostomella* (*Monticulipora*) *tumida*, on the other hand.

As regards their *geological distribution*, the forms usually regarded as Monticuliporoids are exclusively Palæozoic, and range from the Ordovician to the Permian inclusive. In the Ordovician rocks, in particular, Monticuliporoids are enormously abundant, and they also constitute a conspicuous feature in the Silurian deposits, while their number is much reduced in the Devonian, Carboniferous, and Permian strata. As a rule, particular types are confined to special geological horizons, but the vertical distribution of the group still requires to be worked out in detail. So far as certainly known, the genus *Stenopora*—a name which has served to cover many different types of the Monticuliporoids—is confined exclusively to the Carboniferous and Permian deposits. It is not at all improbable that representatives of the Monticuliporoids will be found to have survived into the Secondary period, while there are even Tertiary fossils which show remarkable points of resemblance to this ancient group of organisms.

With regard to the *classification* of the Monticuliporoids, two principal types of structure may be recognised, represented respectively by the genera *Monticulipora* and *Fistulipora*, as these are now restricted. These two types of structure may be taken with convenience as the foundation of the two families of the *Monticuliporidæ* and *Fistuliporidæ*. It must be admitted, however, that these two families are connected together by transitional forms; and it is probably impossible, in the present state of our knowledge, to so define them as to render them mutually exclusive.

Monticuliporidæ.

The skeleton of the *Monticuliporidæ* is very variable in form, and may be either composed of essentially similar tubes throughout, or may be made up of large tubes ("autopores") and of a limited number of smaller, closely tabulate tubes ("mesopores"). The interstitial tubes or "mesopores" are not sufficiently developed to isolate the autopores, while they are provided with complete walls and their tabulæ are straight. "Acanthopores" are very commonly present. Septal spines are rarely developed. The mode of growth of the skeleton is by intermural gemmation, commonly associated with fission.

This family includes the genera *Monticulipora*, *Monotrypa*, *Mono-*

trypella, *Dianulites*, *Diplotrypa*, *Dekayia*, *Stenopora*, &c., and ranges from the Ordovician to the Permian period.

The type of the genus *Monticulipora* is the *M. mammulata*, D'Orb., of the Ordovician rocks of North America, which Mr Ulrich identifies with the form described by the writer under the name of *Peronopora molesta*. In this form, the corallum (fig. 224, A) has usually the shape of a laminar erect expansion, composed of two layers of tubes which open on the two sides of the frond. The large tubes or "autopores" are placed close together, and just before reaching the surface their walls become

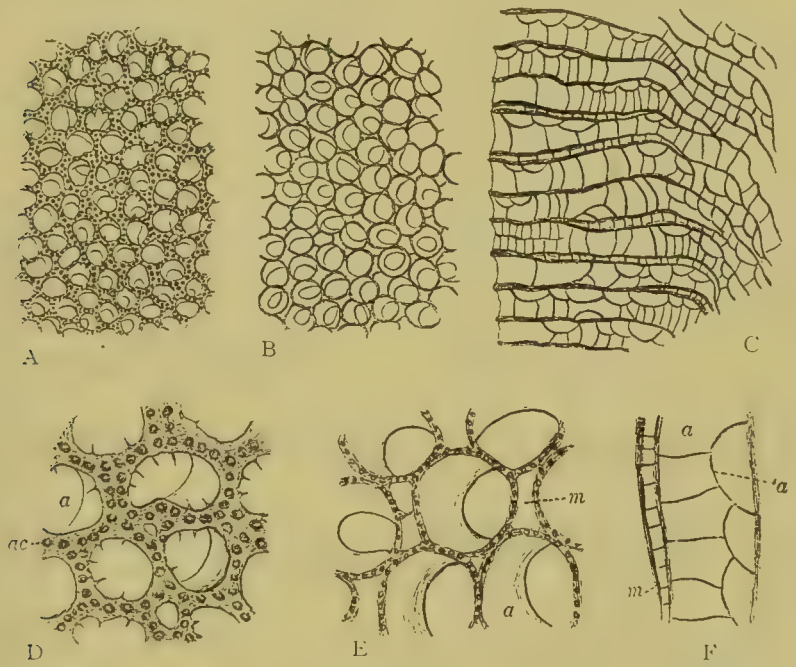


Fig. 230.—Morphology of *Monticulipora mammulata*, D'Orb. (=*Peronopora molesta*, Nich.), Ordovician, Cincinnati. A, Tangential section taken immediately below the surface, enlarged twenty times. B, Tangential section taken at a greater depth below the surface, similarly enlarged. C, Vertical section, showing one side of the double frond, similarly enlarged. D, E, and F, Portions of the preceding sections enlarged forty times: *a*, Autopores; *m*, Mesopores; *ac*, Acanthopores; *ta*, One of the "cystoid" tabulæ of an autopore, the rest of the tube being crossed by straight tabulæ. (Original.)

considerably thickened; hence there is a considerable difference between sections taken just below the actual surface (fig. 230, A and D) and those taken at a little depth (fig. 230, B and E). Interstitial tubes or mesopores are developed in small number, and are easily recognised in long sections by their close tabulation (fig. 230, F). Acanthopores are developed in great numbers, and form a ring round each autopore (fig. 230, D), but they are difficult to recognise except in tangential sections taken close to the surface. The autopores are furnished with two sets of tabulæ, each tube showing a series of vesicular or "cystoid" tabulæ on one side (fig. 230, F, *ta*) with a series of straight tabulæ in the other half of the tube. Owing to this peculiarity in the tabulation of the autopores, tangential sections (fig. 230, B) exhibit the cut edges of the cystoid tabulæ in the

form of a curved or horse-shoe-shaped line in the interior of each autopore. In some examples of this species, the autopores are provided with radially disposed pseudoseptal spines (fig. 230, D), but these are not recognisable in other specimens.

Of the remaining genera of the *Monticuliporidæ* only two or three can be briefly noticed here. The genus *Monotrypa* is characterised by the fact that the tubes are essentially similar to one another, being polygonal, thin-walled, and furnished with few remote tabulæ, while mesopores are absent, as, usually, are acanthopores also. The genus ranges from the Ordovician into the Devonian. *Monotrypella* is very similar to *Monotrypa*, but the corallites become thickened by stereoplasma as they approach the surface, their walls, however, always remaining distinct (fig. 231).

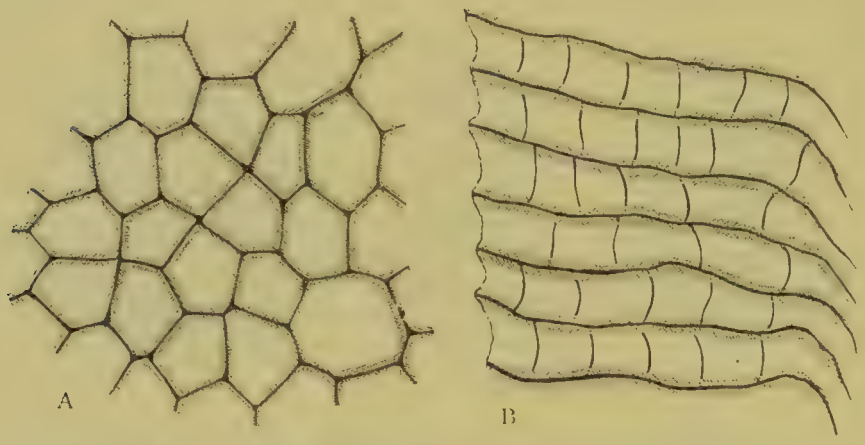


Fig. 231.—Sections of *Monotrypella pulchella*, E. and H., from the Wenlock Limestone of Britain, enlarged about eighteen times. A, Tangential section; B, Longitudinal section. (Original.)

The Ordovician genus *Dianulites* (as based upon *Dianulites fastigiatus*, Eichw.) is essentially similar to *Monotrypa* as regards the nature and structure of the corallites, but the corallum is inversely conical in form, and is provided with a striated epithecal membrane, so that the calices open at the upper end of the colony only, and the organism is superficially quite like a simple coral in appearance. The genus *Amplexopora*, ranging from the Ordovician to the Carboniferous, nearly resembles *Monotrypella* in structure; but numerous acanthopores are developed, which often form complete rings round the autopores. *Dekayia*, again, resembles *Monotrypella* in having only a single set of tubes, without mesopores, but the walls of the autopores are united, and there are numerous large acanthopores, the apices of which project above the surface as prominent blunt spines (fig. 227). The genus is only known from the Ordovician rocks.

Lastly, in the Carboniferous and Permian genus *Stenopora*, the colony consists of oval or circular or subpolygonal autopores, the walls of which on approaching the surface become thickened with annular deposits of stereoplasma, which are separated by unthickened nodes (fig. 232, C), this peculiarity giving a very characteristic appearance to longitudinal sections. In the centre of the colony the corallites are polygonal and thin-walled, and do not exhibit the characteristic annulations of the genus.

Mesopores are not developed, but there are usually numerous acanthopores (fig. 232, A and B). The tabulæ are usually straight and complete, but they are sometimes perforated by central apertures (fig. 232, C). The walls of the autopores in *Stenopora* have been described as being perforated by mural pores, but, as previously noted, the researches of

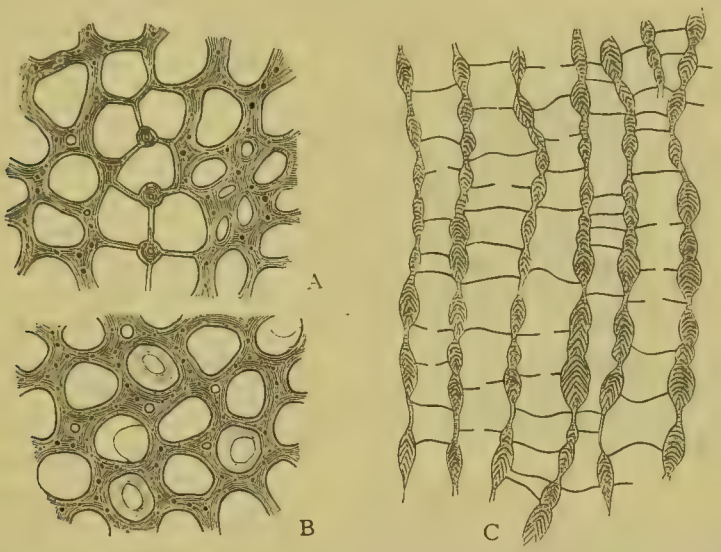


Fig. 232.—Sections of *Stenopora Howsii*, from the Carboniferous rocks of England, enlarged about eighteen times. A and B, Tangential sections; C, Longitudinal section, showing the periodic thickenings of the walls of the tubes. (Original.)

Waagen and Wentzel have rendered it certain that the supposed mural pores must be otherwise explained, and that the walls of the tubes are really imperforate.

FISTULIPORIDÆ.

The skeleton in this family is of very variable form, and is composed of large tubes ("autopores") which are in general more or less completely isolated (fig. 233) by the development of a copious series of smaller tubes ("mesopores"), these latter being often aggregated into star-shaped groups or "maculæ," which serve as centres of growth for the colony. The walls of the autopores are either completely unthickened (*Callopora* and *Prasopora*), or are specially thickened on one side (*Fistulipora*). The mesopores are furnished with more numerous tabulæ than the autopores; and in some cases (*Fistulipora*) their walls are incomplete, thus allowing their tabulæ to coalesce so as to form an interstitial tissue of lenticular vesicles. The mode of increase as regards the autopores is typically by "cœnenchymal gemmation," the mesopores increasing by means of fission. Pseudoseptal spines are occasionally developed, and pseudoseptal folds are commonly present. Acanthopores are occasionally, but not usually, developed.

Since "cœnenchymal gemmation" is at present only known as occurring (apart from the present family) in the unquestionably Actinozoan groups of the *Helioporidæ* and *Heliolitidæ*, it would seem that the presence of this mode of increase in the Fistuliporoids, first pointed out by Waagen, is an almost incontrovertible proof that the latter should be referred to the Alcyonarian Zoophytes. If this be admitted, however, it would follow, almost inevitably, that the *Monticuliporidæ* should also be regarded as Alcyonarians, since there exists an exceedingly close relationship between these and the Fistuliporoids. No arrangement, in fact, which would refer *Fistulipora* and *Callopora* to one great division of the animal kingdom (*Cœlenterata*), and would place *Monticulipora*, *Diplotrypa*, and allied types in another great division (*Polyzoa*) could possibly be sustained.



Fig. 233.—Tangential section of *Fistulipora trifoliata*, from the Middle Devonian of Gerolstein, enlarged about forty times, showing the trifoliate autopores (*a*) and the interstitial mesopores (*m*). (After Nicholson and Foord.)

The type-genus of the Fistuliporoids is *Fistulipora* itself, in which the variously shaped corallum is composed of oval or cylindrical autopores, which are furnished towards one side with two longitudinal folds ("pseudosepta"), giving to the tubes in cross-sections a characteristic bilobed or trifoliate appearance (fig. 233), and which are separated by one or more rows of mesopores (fig. 234, D). The walls of the mesopores are ncompletely developed, and their tabulæ therefore coalesce to give rise ɔ a vesicular tissue occupying the spaces between the autopores (fig. 234, E). Acanthopores are occasionally developed, and in some cases pseudoseptal spines have been observed.

The species of *Fistulipora* are Silurian, Devonian, and Carboniferous, and are in general readily recognised by the trifoliate form of the autopores in cross-sections, the abundance of the mesopores, and the fact that the tabulæ of the mesopores coalesce to form a tissue of lenticular vesicles occupying the spaces between the autopores, and resembling the similarly formed vesicles which separate the autopores in *Plasmopora* and *Propora*. In some forms, the two pseudoseptal folds which are so characteristic of the genus are little developed (compare fig. 234, D, with fig. 233), and the trifoliate shape of the tubes is proportionately obscured. The peculiar horse-shoe-shaped sinus along one side of the autopores, formed by the pseudosepta, has been considered, with much probability, as corresponding in the living animal with a ciliated groove ("siphonoglyphe") such as is found in the œsophagus of the Alcyonarians. Another characteristic feature in many species of the genus is that the portion of the wall bounding the sinus just spoken of is considerably thickened, and

in well-preserved specimens sometimes exhibits a peculiar striated aspect, as if it were finely tubulated.

The genus *Callopora*, as maintained by Waagen, must find a place in the immediate neighbourhood of *Fistulipora*. The typical species of this genus resemble *Fistulipora* in most respects, but the autopores are, as a rule, without pseudoseptal folds, and the mesopores have complete walls and are furnished with straight tabulæ, which do not coalesce to form an interstitial vesicular tissue (fig. 225, B). In some cases, traces of pseudo-

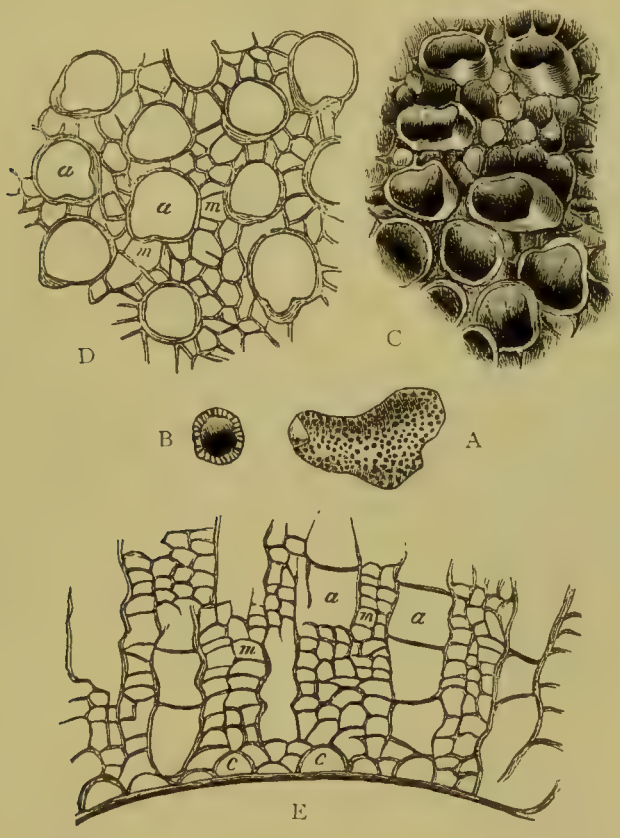


Fig. 234.—*Fistulipora incrustans*, from the Carboniferous rocks of England. A, A colony growing on the stem of a Crinoid, of natural size; B, Broken extremity of the same, showing the thickness of the colony; C, Portion of the surface, enlarged almost twenty times; D, Tangential section, similarly enlarged; E, Vertical section, similarly enlarged. *a*, Autopores; *m*, Mesopores; *c*, Primordial tubes of the colony. (After Nicholson and Foord.)

septa are present in the autopores, and in one species (*Callopora Foordii*, fig. 229) these structures are exceptionally developed. Pseudoseptal spines are occasionally present in this genus. The walls of the autopores in *Callopora* are not specially thickened in the "mature" region of the corallum, as is shown by the structure of the type-species of the genus (*Callopora elegantula*, Hall). Hence, forms like *Callopora (?) ramosa*, E. and H., of the Ordovician rocks of North America, which have been referred here by Mr Ulrich, must find a place elsewhere, as the autopores become markedly thickened in the peripheral portion of the corallum.

The species of *Callopora* appear to be confined to the Ordovician and Silurian rocks.

Lastly, the Ordovician genus *Prasopora* differs from *Callopora* mainly in the fact that the autopores are furnished marginally with a series of vesicular or "cystoid" tabulæ, which enclose a central area traversed by straight tabulæ.

LITERATURE OF MONTICULIPOROIDS.

1. "Polypiers Fossiles des Terrains Paléozoiques." Milne-Edwards and Haime. 1851.
2. "Die Chætetiden der ostbaltischen Silurformation." Dybowski. 1877.
3. "On the Structure and Affinities of the Genus Monticulipora and its Subgenera." Nicholson. 1881.
4. "American Palæozoic Bryozoa." Ulrich. (A series of papers in the 'Journal of the Cincinnati Society of Natural History,' 1879-1884).
5. "Contributions to the Micro-Palæontology of the Cambro-Silurian Rocks of Canada." Foord. 1883.
6. "On the Genus Fistulipora, M'Coy, with Descriptions of several species." 'Annals and Magazine of Nat. Hist.' 1885. Nicholson and Foord.
7. "On the Tasmanian and Australian Species of the Genus Stenopora, Lonsdale." 'Annals and Magazine of Nat. Hist.' 1886. Nicholson and Etheridge, jun.
8. "The Salt-Range Fossils—Cœlenterata." 'Palæontologia Indica. 1886. Waagen and Wentzel.

CHAPTER XXII.

SUB-KINGDOM IV.—ECHINODERMATA.

General Characters of the Echinodermata.

The sub-kingdom of the *Echinodermata* comprises the animals usually known as Sea-urchins, Star-fishes, Brittle-stars, Sea-cucumbers, Sea-lilies, &c., and may be briefly defined as follows:—

Simple marine organisms, which are mostly bilaterally symmetrical when young, but which in the adult condition have this bilateral symmetry more or less extensively masked by a radial (usually pentamerous) arrangement of their parts. An alimentary canal is present, with or without a distinct anus, separate from the proper body-cavity. A system of water-vessels, often communicating directly with the exterior, and generally connected with protrusible tubes ("feet"), is present. The nervous system is radiate, consisting of an œsophageal ring and radiating branches. The integument is characteristically hardened by the deposition in it of carbonate of lime in the form of plates, granules, or spicules.

The adult Echinoderms always exhibit a more or less conspicuous radiate structure, the symmetry of the body being essentially pentamerous; but the larval forms are usually distinctly bilateral, and bilateral symmetry is in general more or less clearly recognisable in the fully grown animal. The radial symmetry of the body of the adult is exhibited not only in the external skeleton, but also in many of the internal organs, and especially in the nervous and ambulacral systems. The alimentary canal, unlike that of the Cœlenterates, is always completely shut off from the general cavity of the body, a mouth being always present, and an anal aperture usually existing as well. When a mouth and anus are present, these openings may be at opposite poles or on the same side of the body, the mouth being usually central in position, while the anus may be completely excentric. In the free-living Echinoderms, the mouth is usually either terminal and placed in front, or is situated in the centre of the in-

ferior surface of the body. On the other hand, in the stalked Crinoids and certain other forms, the ventral surface is directed upwards, and the mouth is thus placed on the superior aspect of the body.

Among the most characteristic of all Echinodermal structures are the so-called "water-vessels" or "ambulacral" vessels. This system consists of a series of musculo-membranous tubes filled with a watery fluid, and connected with the function of respiration, while at the same time commonly subserving locomotion. It consists essentially (fig. 235) of a circular vessel which surrounds the commencement of the alimentary canal, and gives off secondary vessels in a radiating manner. The "radiating vessels" usually give off at right angles numerous short lateral tubes (the "tube-feet" or "pedicels"); and the "circular vessel" is generally placed in communication with the exterior by a special canal ("stone-canal" or "water-tube") which opens on the surface by a spongy calcareous plate ("madreporite"). Though commonly subserving locomotion, the ambulacral vessels are probably primarily respiratory in function; and they not uncommonly give off leaf-like or branched external processes ("ambulacral gills"), which serve as respiratory organs. There is also a second vascular system, consisting of an oral ring and radial trunks, which are situated between the water-vessels and the nerve-bands. The oral ring is in relation with a peculiar organ, formerly described as a heart, but probably to be regarded as a kidney, which in many Echinoderms seems to communicate with the exterior by means of the madreporite.

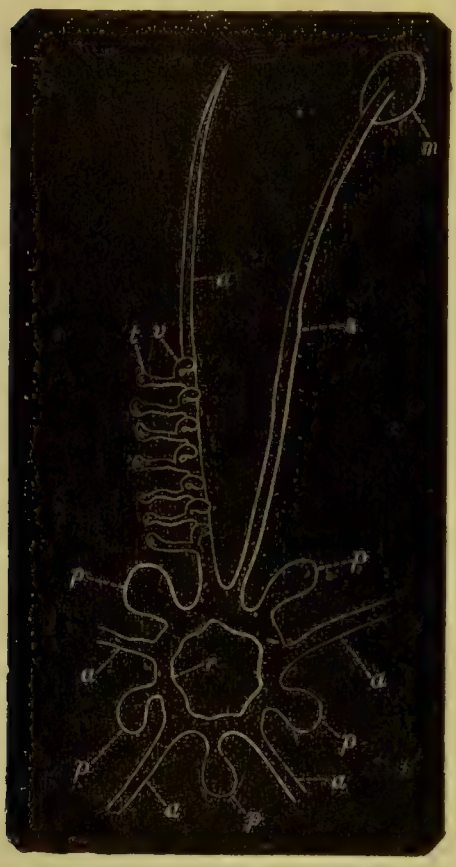


Fig. 235.—Diagram of the ambulacral system of *Echinus*. *m*, Madreporite; *s*, Stone-canal; *r*, Central œsophageal ring; *p p*, Polian vesicles; *a a*, Radiating ambulacral vessels. Only the bases of four of the radiating vessels are shown; and a few of the tube-feet (*t*), with their secondary vesicles or "ampullæ" (*v*), are shown on one side of one of the radiating canals.

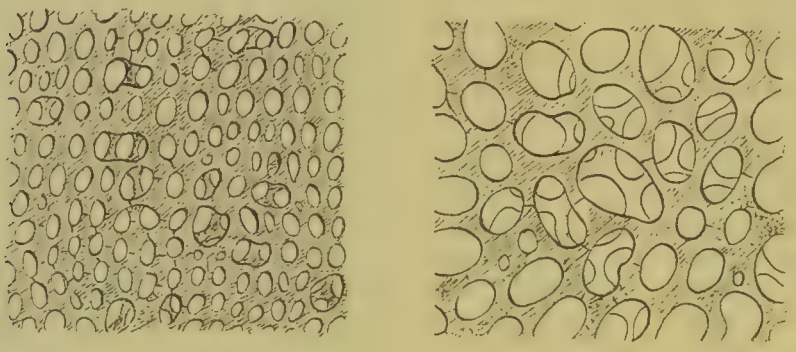
The sexes are almost always distinct in the Echinoderms, and the reproductive organs are usually lodged in the interior of the body, definite openings for the escape of the generative elements existing

in the body-wall. In the Crinoids, on the other hand, the reproductive organs are lodged in the "arms," and permanent generative apertures are rarely, if ever, present. As regards their position, the generative glands (ovaries or testes) alternate in the Echinoderms generally with the radiating nerve-cords and ambulacral vessels, and are therefore "interradial," while the latter are "radial"; but in the Crinoids the genital cord, being lodged in the arms, is necessarily radial in position.

The integument of the Echinoderms has the power of secreting carbonate of lime, and a more or less definite integumentary skeleton is thus usually produced. Not only is this exoskeleton in general readily preserved in the fossil state, but its minute structure is so characteristic that even the smallest fragment can usually be recognised with certainty by the help of the microscope. In the first place, the calcareous tissue of the Echinodermal exoskeleton has a very characteristic crystalline structure. "Each plate, each spine, and each joint is mineralogically and optically, as it were, made out of a single crystal of calcite, having its principal axis perpendicular to the plane of the plate, or parallel to the axis of a spine or joint, the growth from first to last being in perfect crystalline continuity" (Sorby). In recent Echinodermal skeletons, this crystalline structure is only recognisable by the optical phenomena displayed by thin sections under the microscope; but the skeleton of fossil forms, as the result of mineralisation, usually exhibits, in its minutest fragments, the unmistakable rhombohedral cleavage of calcite. In the second place, the skeleton of the Echinoderms has an equally characteristic organic structure, being made up of reticulated and anastomosing calcareous rods, which are produced by the calcification of a network of organic fibres, the uncalcified intervals of which are filled in the fresh state with living matter. All Echinodermal ossicles and plates exhibit this characteristic netted structure (fig. 236), but different forms differ in the size and disposition of the meshes; the commonest and simplest arrangement being that of parallel strata of perforated calcareous laminæ connected with one another by vertical pillars. In other cases, as in the spines of the Echinoids, the structure consists of radially-disposed, vertical, netted plates united by numerous short horizontal rods; and other types exhibit other special modifications.

In altered specimens, the minute reticulated structure of the skeleton may be largely obliterated, or even wholly unrecognisable, but the characteristic cleavage usually remains. Owing to the persistence of the characteristic micro-structure of the skeleton, even detached and otherwise indeterminable fragments of Echinoderms can commonly be recognised with certainty under the microscope, and valuable assistance is thus often afforded to the palæontologist

in his researches. Thus the singular fossils described by Eichwald under the name of *Bolboporites* can by this means be clearly determined to be of Echinodermal origin. These curious remains occur in the Ordovician rocks of Russia and Canada, and though variable in shape, have most commonly the form of inversely conical, ovoid, or clavate bodies, about a quarter of an inch or less in their long diameter, and composed of calcite with its characteristic cleavage. The narrower end of the body is usually smooth, and the sides or upper surface generally pitted with shallow depressions. Described originally as corals, the microscopic appearances of thin sections render it certain that the fossils placed under *Bolboporites* are parts



A B

Fig. 236.—Minute structure of Echinodermal plates. A, Part of a small plate (madreporite?) of an Echinoderm from the Carboniferous rocks of Scotland, highly magnified; B, Part of an interambulacral plate of *Lepidocentrus*, from the Devonian of the Eifel, highly magnified. (Original.)

of the exoskeleton of some Echinoderm. It is difficult to speak precisely as to their nature, but they may be compared with the large tubercles or swollen spines which are developed in the integument of certain Star-fishes (*e.g.*, *Pentaceros*).

As regards their *classification*, the *Echinodermata* may be divided into seven primary groups, which are now usually regarded as classes—viz., the *Crinoidea*, *Cystoidea*, *Blastoidea*, *Ophiuroidea*, *Asteroidea*, *Echinoidea*, and *Holothuroidea*. Of these, the first is to a considerable extent extinct, and the two next are entirely so; while they exhibit certain structural peculiarities which separate them from the other classes. More particularly, the members of these three classes—viz., the Crinoids, Cystoids, and Blastoids—all possess a dorsally-developed, jointed calcareous stalk, which serves to fix them to foreign objects, and which may be only temporarily present. From the presence of this jointed stem, these three classes are grouped together in a single great division, under the name of *Pelmatozoa*. On the other hand, the Echinoids, Asteroids, Ophiuroids, and Holothuroids are devoid of this stalk at all periods of develop-

ment, and usually creep about by the aid of their tube-feet, with the oral surface of the body turned downwards. They are therefore grouped together in a common division under the name of *Echinozoa.*

As regards their *distribution*, all the recent Echinoderms are marine, and from their habit of life and their possession of a calcareous exoskeleton, the members of this sub-kingdom are largely represented as fossils, ranging from the Upper Cambrian period onwards. The classes of the *Cystoidea* and *Blastoidea* are not only extinct, but are exclusively Palæozoic; while in the *Crinoidea* we have a group which has passed its prime, and appears to be verging on extinction. On the other hand, the classes *Echinoidea*, *Asteroidea*, *Ophiuroidea*, and *Holothuroidea* appear to have attained their maximum of development at the present day. The *Asteroidea* and *Ophiuroidea* commence in the Ordovician period. The *Echinoids* commence in the Ordovician, but reach no marked development till we enter upon Mesozoic deposits. Lastly, the *Holothurians*, as might be expected from the soft nature of their integuments, are hardly known as fossils, though they seem to have existed at any rate as early as the Carboniferous period.

CHAPTER XXIII.

DIVISION A.—ECHINOZOA.

Class I. Echinoidea.

The members of this class—commonly known as Sea-urchins—are characterised by the possession of *a more or less globular, heart-shaped, discoidal or depressed body, encased in a "test" or shell, which is composed of numerous calcareous plates, in general immovably connected together. The intestine is convoluted, and there is a distinct anus. The mouth is always situated on the inferior aspect of the body, but the position of the vent varies.*

The ambulacral system of the Echinoids consists of its usual parts, and the five radial vessels given off from the circular œsophageal ring are situated within the shell of the animal. It follows from this that the tube-feet given off from the radial vessels can only reach the exterior by passing through perforations in the plates of the calcareous test. Hence the outer surface of a Sea-urchin exhibits five longitudinal areas which are "radial" in position and correspond with the five radiating ambulacral vessels, and the plates of which are more or less extensively perforated for the protrusion of the tube-feet. These so-called "ambulacral" or "poriferous" areas are separated by five zones which are "interradial" in position, have imperforate plates, and are known as the "interambulacral" areas. The external opening of the ambulacral system is closed by a spongy or porous plate—the "madreporite"—which is almost invariably situated on the apex of the test in one of the interradii. In the extinct *Echinocystites* (*Cystocidaris*) alone the madreporite is removed from its normal position, and is placed "close to the apical pole."

As regards the digestive system, the mouth is always placed on the under surface of the body, and may be central or excentric in position. The mouth is sometimes edentulous, but in other cases a complicated apparatus of calcareous teeth is developed. The anus

in many cases is placed at the summit of the test, and is surrounded by the so-called "apical disc" or "dorso-central system"; but it is in other cases marginal or submarginal, being then separated from the apical disc, and being almost always situated in the posterior interradius. In *Echinocystites* (*Cystocidaris*) alone the anus is excentric and interradial, but is placed near the apex.

The radial nerve-cords run along with the radiating ambulacral vessels in the inside of the shell, and become connected at their terminations with a series of perforated plates ("ocular plates") which form part of the so-called "apical disc," and which are "radial" in position. The generative glands occupy the "interradial" areas, and their ducts normally open by perforations in the so-called "genital plates," which likewise form part of the "apical disc."

It is necessarily principally with the test of the Echinoids and its appendages that the palæontologist is concerned, and these structures must therefore be considered in some detail. The test of the *Echinoidea* may be regarded as essentially composed of the so-called

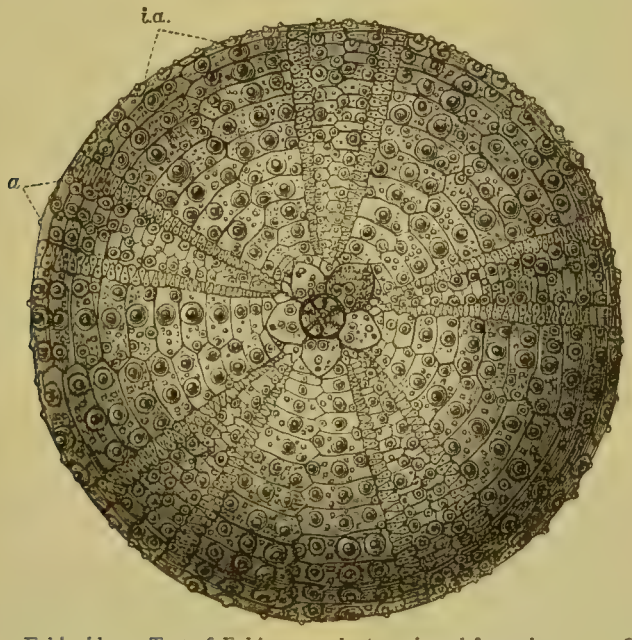


Fig. 237.—Echinoidea. Test of *Echinus esculentus*, viewed from above. *a*, One of the ambulacral areas; *ia*, One of the interambulacral areas.

"corona" and of the "apical disc"; though minor and less constant plates are likewise developed in the membranes surrounding the mouth and anus respectively.

The "corona" forms the main element of the test, and is composed of numerous calcareous plates, more or less firmly united to one another by their edges, arranged in rows, and bearing different

names according to their position and function. In the singular Urchins which constitute the family of the *Echinothuridæ*, as also in various Palæozoic Echinoids, the plates of the test overlap one another in an imbricating manner, so that the shell becomes flexible. As a rule, however, the corona forms an immovable case or box within which the animal is contained; and its growth is carried on by additions made to the edge of each individual plate by the progressive calcification of an organised membrane which passes between the "sutures," or the lines where the plates come in contact with one another. The first circle of the coronal plates is developed round the mouth, and the vertical growth of the test is carried on by the intercalation of successive rows of plates between those already formed and the apical disc.

The corona is composed of ten alternating meridional zones, of which five are radial in position and are perforated, while five are interradial and are imperforate. In all the recent Echinoids, and in all the fossil forms except the Palechinoids and the Cretaceous *Tetracidaris*, each of these ten zones is composed of two rows of plates, there being thus twenty meridional rows of plates altogether. The five interradial zones are spoken of as the "interambulacral areas," and are composed of large-sized plates, which are not perforated by any apertures (fig. 237, *ia*, and fig. 238, *a*). The five radial zones, on the other hand, are termed the "ambulacral areas" or "poriferous zones," and are composed of comparatively small plates, which are perforated by minute pores for the emission of the "tube-feet" (fig. 237, *a*, and fig. 238, *b*). As a rule, the ambulacral pores are in pairs, but in a few cases the pores are unpaired. The pores of each pair may be similar or dissimilar in shape, and in many cases they are united by transverse furrows.

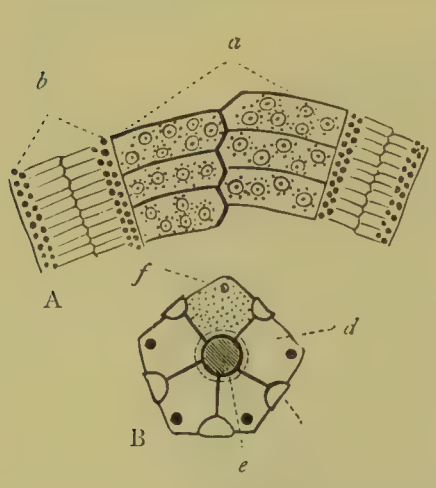


Fig. 238.—A, Portion of the test of *Holectypus hemisphericus*, enlarged, showing an interambulacral area (*a*), and an ambulacral area (*b*). B, Dorso-central system of *Hemicidaris intermedia*, enlarged: *c*, Ocular plate; *d*, Genital plate; *e*, Anal aperture; *f*, Madreporite. (After Forbes.)

In many Echinoids the ambulacral tube-feet can be protruded along the entire length of the ambulacral areas, which are perforated along their entire course from the centre of the base of the corona to the summit of the same, and which are then said to be "perfect" (*ambulacra perfecta*) or "simple" (figs. 237 and 239). In many other Echinoids, on the other hand, the ambulacral areas are not

thus continuously perforated from pole to pole, but they are "interrupted," only their upper portions being regularly poriferous.

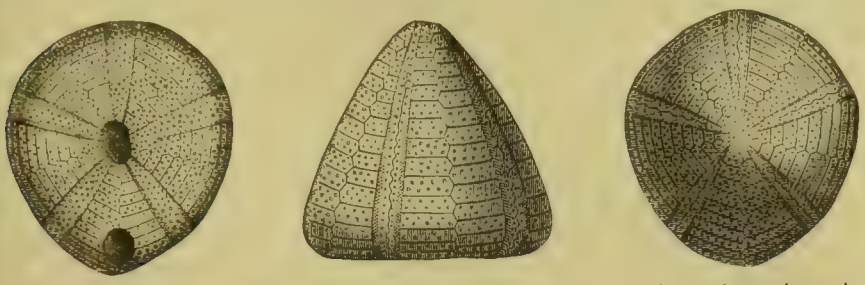


Fig. 239.—*Echinoconus conicus* (=*Galerites albogalerus*). The first figure shows the under surface with the mouth and anus; the middle figure is a side-view; and the right-hand figure shows the upper surface, with the ambulacral areas converging to the apical disc. White Chalk.

In such cases (fig. 240) the ambulacral zones are widened out superiorly, and form a kind of rosette upon the upper surface of the



Fig. 240.—*Scutella subrotunda*, showing petaloid ambulacra. Miocene.

test, when they are said to be "circumscript" (*ambulacra circumscripta*), or "petaloid."

The most important external structures of the corona are the tubercles and spines. The tubercles are rounded elevations upon

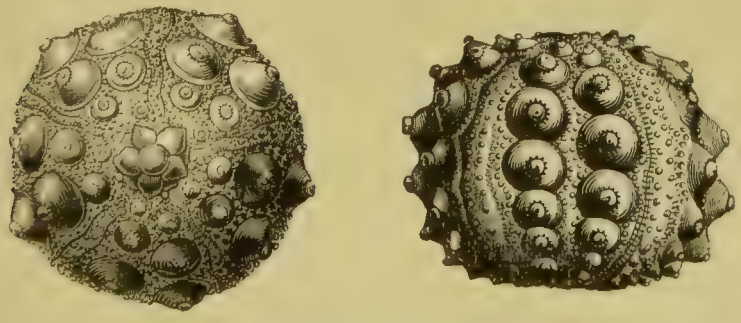


Fig. 241.—*Hemicidaris crenularis*, showing tubercles, the larger of which are perforated, and are surrounded by an areola. Jurassic.

which the spines are carried (fig. 241). They vary much in their dimensions, and receive special names, according to their size or position on the test. Ordinarily the tubercle consists of a rounded

ball or hemisphere (the "mamelon") supported upon a conical process ("the boss") which arises from the plate. The ball of the tubercle may or may not be perforated for the insertion of a ligament which is attached to the articular surface of the spine. In many cases (as in fig. 241) the base of the tubercle is surrounded by a round or oval, smooth and excavated space which is termed the "areola" or "scrobicule."

The spines are movable appendages which are jointed to the tubercles by a sort of "ball-and-socket" or "universal" joint. They are used defensively and in locomotion, and vary much in length and shape. Sometimes they are very minute; at other times they attain a length considerably exceeding the diameter of the test. Sometimes they are slender, tapering, and truly spine-like; at other times they are thickened, ovate, or almost globular (fig. 242). The spine fits on to the rounded head of the tubercle by a concave articular surface ("acetabulum"), and there may or may not be a pit at the bottom of this, for the attachment of the ligament before spoken of. Above the acetabulum or socket of the spine there is a prominent ridge or ring, more or less "milled," for the attachment of the muscular fibres which move the spine.



Fig. 242.—Spine of *Cidaris glandifera*. Jurassic.

At the summit of the corona in all Echinoids is found the single or double row of plates which constitutes the "apical disc" or dorso-central system, corresponding with the "calyx" of the Crinoids. In the most typical forms ("Regular" Echinoids) the plates of the apical disc surround the membrane ("periproct") in which the anus is situated (fig. 243, A); but in the so-called "Irregular" Echinoids (fig. 243, B) the apical disc simply occupies the summit of the test, and the anus is excentric, and is entirely removed from the disc. In its most ordinary condition (as in the genus *Echinus*, fig. 237), the apical disc is composed of ten plates arranged in two alternating rows of five plates each. The uppermost row consists of a cycle of five large plates of a pentagonal form, which are perforated each by the duct of a testis or ovary, and are therefore known as the "genital plates." (In the Palæozoic Echinoids from three to five pores pierce each genital plate.) One of the genital plates is larger than the others, and supports a spongy tubercle perforated by many minute apertures, like the rose of a watering-pot, and termed the "madreporite" or "madreporiform tubercle" (fig. 243, *ma*). The madreporite varies much in size, and sometimes forms almost the whole of the apical disc. The genital plates occupy the summits of the interambulacral areas, and are therefore interradial in position. Wedged in between the genital plates, and occupying the summit

of the ambulacral areas, are five smaller, heart-shaped or pentagonal plates, which are known as the "ocular plates," each of which is perforated by a minute pore lodging the rudimentary sense-organ ("ocellus") in which the radial ambulacral nerve terminates.

The anus in the Echinoids is situated in a membrane ("periproct"), which is more or less largely hardened by the development in it of small calcareous plates, which may be wholly irregular, or may form one or more regular cycles (fig. 243, *an*). As previously seen, the periproct in the "Regular" Sea-urchins is placed in the centre of the apical disc (fig. 243, A), whereas in the "Irregular" Urchins it has no connection with this structure, and is wholly

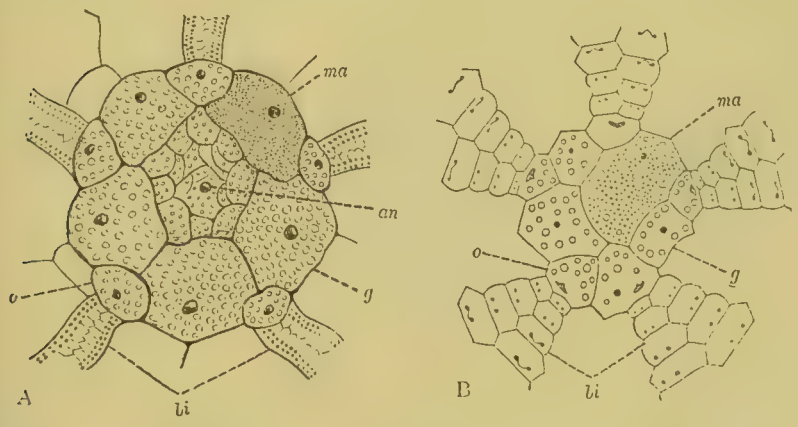


Fig. 243.—A, Apex of the shell of *Cidaris imperialis* (Recent), enlarged, after Van der Hœven; B, Apex of the shell of *Micraster* (Cretaceous), showing the condition of the apical disc in the "Irregular" Echinoids, after Zittel. *an*, Anus, surrounded by the plated "periproct"; *g*, One of the genital plates; *o*, One of the ocular plates; *ma*, Madreporite; *bi*, the two posterior ambulacral areas, constituting the "bivium."

excentric. The mouth in the Echinoids, like the anus, is situated in a coriaceous membrane ("peristomial" membrane) hardened by plates and granules of lime. Hence in macerated or fossil specimens the under surface shows, in place of the true mouth-opening, a wide vacant space ("peristome") originally occupied by the peristomial integument. The peristome may be rounded or oval, or bilabiate, or, very commonly, pentagonal, often with incisions at the angles for the accommodation of the so-called "oral gills."

The internal skeleton of the Echinoids is represented by the so-called "auriculæ" of certain types. These are calcareous arches which are ambulacral or "radial" in position, and spring from the inner surface of the lower edge of the test, just where the imperfectly calcified peristomial membrane begins. Each forms an arch over one of the radiating ambulacral vessels; and the auricles correspond, therefore, with the so-called "ambulacral ossicles" of the Star-fishes.

Though superficially conspicuously "radial" in its symmetry, the test of the Sea-urchins can nevertheless be shown, with more or less clearness, to have also a bilateral symmetry. This can be demonstrated by the position of such an unpaired organ as the "madreporite," and is more conspicuously exhibited in the "Irregular" Sea-urchins than in the "Regular" forms, though recognisable even in the latter. Thus, if the test of a Regular Sea-urchin (figs. 237 and 243) be viewed from above while held in such a position that the madreporite is placed on the side farthest from the spectator and on his right hand, it will be seen that facing the spectator is an unpaired ambulacral area ("radius"), while on the side nearest him is an unpaired interambulacral area ("interradius"). A line drawn through the centre of these two unpaired areas gives a middle line to the body, the structures on either side being for the most part symmetrically disposed. It will further be seen that three ambulacral areas (the "trivium") are directed towards the side farthest from the spectator (the "anterior" side); while two (the "bivium") are directed "posteriorly," or towards the side facing the spectator. The unpaired ambulacral area is therefore "anterior," and the unpaired interambulacrum is "posterior." In the "Irregular Sea-urchins" the bilaterality is still more marked, the unpaired anterior ambulacrum being usually different to the others in form or size; while the anus is commonly placed on the ventral side of the body, in the unpaired posterior interambulacrum.

As regards *classification*, the class of the *Echinoidea* is divided by Zittel into the two orders of the *Palechinoidea*, in which the test consists of more or fewer than twenty meridional rows of plates, and the *Euechinoidea*, in which there are constantly twenty rows of plates in the shell. The Palechinoids comprise the three groups of the *Cystocidaridæ*, *Bothriocidaridæ*, and *Perischoëchinidæ*, and the Euechinoids are divided into the two groups of the *Regulares* and *Irregulares*, according as the test is of the "regular" or "irregular" type.

As regards their distribution in time, all the Echinoids of the Palæozoic formations except *Eocidaris* belong to the order of the *Palechinoidea*, and a single member of this division (*Anaulocidaris*) is known to exist in strata of Triassic age, the division being otherwise unrepresented in Mesozoic or Tertiary deposits. The earliest types of the Palechinoids are found in the Ordovician rocks. On the other hand, the Euechinoids make their first appearance, so far as certainly known, in the Permian (*Eocidaris*), and attain a marvellous development in the Jurassic and Cretaceous periods. In the Tertiary rocks, on the contrary, the number of known fossil forms is reduced, most of the Kainozoic types being characteristic of shallow water, and many of the genera being still in existence. Upon the whole, the Euechinoids may be considered as having attained their maximum development in the period of the Chalk.

In the following condensed account of the characters and geological distribution of the chief groups of the Echinoids, the less important types are necessarily omitted. The arrangement adopted by Zittel has been followed in the main.

Order I. Palechinoidea.

This order comprises all those Urchins in which *the test is made up of more or (rarely) fewer than twenty meridional rows of plates: while the plates of the apical disc are perforated by two or more pores each, or may be in part imperforate.* As a general rule, there is an increase in the number of rows of plates forming the test of the Palechinoids, as compared with that of the Euechinoids, the interambulacral areas usually consisting of more than two rows of plates each (fig. 244). In some cases, the ambulacral as well as the interambulacral areas may consist of more than two rows of plates each, as, for example,

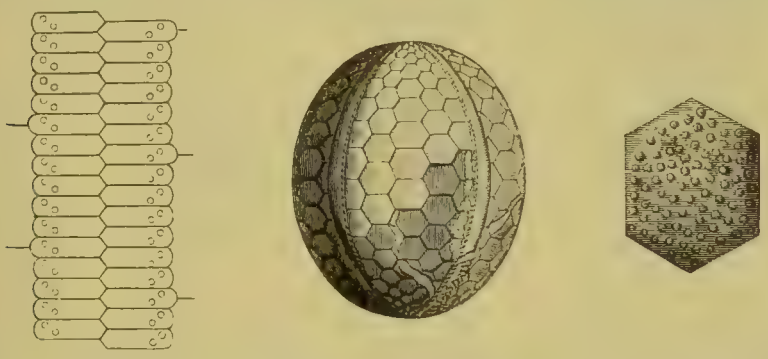


Fig. 244.—*Palæchinus ellipticus.* The left-hand figure shows a portion of an ambulacral area enlarged. The right-hand figure exhibits a single interambulacral plate.

in the genus *Melonites* (fig. 247). On the other hand, in the genus *Bothriocidaris* there is a reduction instead of a multiplication of the normal number of rows of plates in the test, the interambulacral areas consisting of one row of plates only. Furthermore, in many of the Palechinoids the test becomes more or less flexible, owing to the fact that the plates are not suturally united by their margins, but overlap by means of bevelled edges, the structure of the shell thus resembling that seen in the existing group of the *Echinothuridæ*. In all the Palechinoids there is a large peristomial aperture, and a well-developed masticatory apparatus ("Aristotle's lantern") was present. In all except *Echinocystites* (*Cystocidaris*), the test is "regular," the anus being placed at the summit of the shell and surrounded by the apical disc. The genital plates are perforated by from three to five pores each; and the ocular plates have usually two pores each, but are in other cases imperforate (fig. 244).

The order of the Palechinoids includes the three sub-orders of the *Cystocidaridæ*, *Bothriocidaridæ*, and *Perischoëchinidæ*, all of which are wholly confined to the Palæozoic period, with the exception of the last, which is represented in the Trias by the imperfectly known genus *Anaulocidaris*. It is interesting to note that this ancient

series of Echinoids possesses both "regular" and "irregular" types, and in this respect runs parallel with the later group of the Euechinoids. It is to be remembered, however, that the abnormal *Echinocystites* (*Cystocidaris*) exhibits an irregularity of structure which differs considerably from that which characterises the "Irregular" Euechinoids.

The sub-order of the *Cystocidaridæ* comprises only the aberrant genus *Echinocystites* (=*Cystocidaris*, Zittel), in which the interambu-

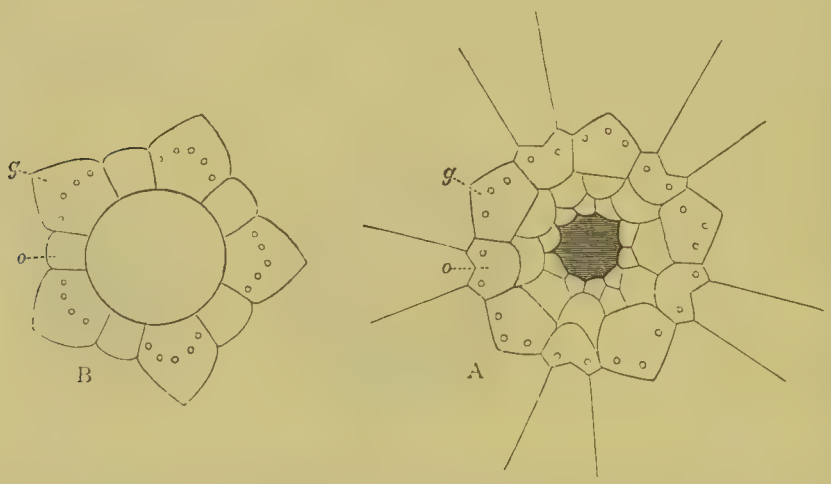


Fig. 245. — A, Apical disc of *Palæchinus*, enlarged (after Baily); B, Apical disc of *Melonites* (after Meek and Worthen): *g*, One of the genital plates; *o*, One of the ocular plates.

lacral zones are composed each of several rows of plates, and the anus is excentric. The two known species of the genus are found in the Silurian rocks of Britain.

The test in *Echinocystites* is spheroidal or ovoid, with narrow ambulacral and broad interambulacral areas, the latter being formed by several irregular rows of imbricated calcareous plates, carrying spines. The mouth is on the under surface, central in position, with a well-developed masticatory apparatus; while the anus is excentric, but has the unique position of being not widely remote from the apex in one of the interambulacral spaces. The madreporite is also quite peculiar in not being at the apex of the shell, but in being placed excentrically in one of the interambulacra. Another remarkable point is that the anus is closed by a valvular pyramid of calcareous plates, a feature highly characteristic of the Cystideans.

The sub-order of the *Bothriocidaridæ* includes the single genus *Bothriocidaris*, in which the interambulacral areas are composed each of a single row of plates, and the anus is placed in the centre of the apical disc. The two known species of the genus have been found in the Ordovician rocks of Russia (Esthonia).

The test in *Bothriocidaris* is spheroidal and "regular," the anus being situated in the centre of the apical disc, and the ambulacra being "perfect." The plates of the test are immovably connected, and the interambulacral zones are composed of a single row of plates only, while the ambulacral zones have two rows each (fig. 246, *a*). There are thus fifteen meridional rows of plates in the test in all. The peristomial



Fig. 246.—*Bothriocidaris Pahleni*, Ordovician. *a*, The test viewed sideways, of the natural size; *b*, The apical disc and anus, enlarged; *c*, The mouth, enlarged. (Copied from Zittel, after Fr. Schmidt.)

membrane (fig. 246, *c*) is furnished with triangular valvular plates surrounding the mouth-opening, and similar plates encircle the aperture of the anus (*b*).

The sub-order of the *Perischoëchinidæ* comprises all the known remaining types of the Palechinoids, and is characterised by the fact that the test is composed of more than twenty meridional rows of plates, and is "regular" in type, the anus being situated in the centre of the apical disc. The interambulacral areas always possess more than two rows of plates each, and the ambulacral areas likewise may consist of more than two rows each (as in *Melonites* and *Oligoporus*, fig. 247). The mouth is placed in the centre of the lower surface, and is furnished with a masticatory apparatus, while the anus is situated at the summit of the test. The genital plates have from two to five pores, and the ocular plates may have two pores each or may be imperforate (fig. 245). Very commonly the test becomes more or less flexible in consequence of the imbrication of its component plates, the edges of which are often bevelled. All the *Perischoëchinidæ* are Palæozoic, with the exception of the Triassic genus *Anaulocidaris*. The earliest types are found in the Silurian, but the group attains its maximum in the Carboniferous rocks.

Of the genera of the *Perischoëchinidæ*, *Palæchinus* possesses a spheroidal test (fig. 244), the plates of which abut against one another without any overlapping. The ambulacral areas are comparatively narrow, of two rows only, each plate perforated by two pores. The interambulacral areas are broad, and are composed of from four to eight rows of plates. The apical disc (fig. 245, A) has five triply perforated genital plates, and an equal number of doubly perforated ocular plates (Baily), but the latter are wanting in *P. sphæricus*. A single species of

the genus occurs in the Silurian rocks, but a number of forms are found in the Carboniferous Limestone.

In the genera *Melonites* and *Oligoporus*, of the Carboniferous rocks, we have large spherical Urchins, in which the test appears to have been rigid, though some of the plates are occasionally bevelled off, so as to articulate in an overlapping manner with one another. In *Melonites* (fig. 247) there is a multiplication of the plates of both the interambulacral and ambulacral areas, the former consisting in the middle of seven or eight rows, while the latter are of eight or ten rows, or, in a British species, of from twelve to fourteen rows. The central two rows of ambulacral plates are larger than the rest and elevated above them, and each plate of these areas is doubly perforated. The apical disc (fig. 245, B) is composed of

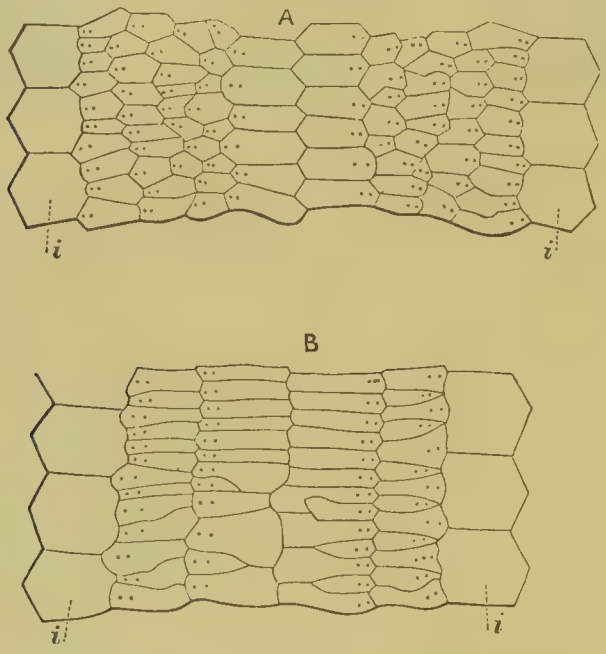


Fig. 247.—A, Portion of an ambulacral area of *Melonites multiporus*. B, Portion of an ambulacral area of *Oligoporus Danæ*: *i*, Lateral row of interambulacral plates. Carboniferous. (Meek and Worthen.)

the normal ten plates, but the ocular plates are sometimes imperforate, and the genital plates are furnished with from three to five pores.

Oligoporus (fig. 247, B) is very similar to *Melonites*, but the ambulacral areas consist each of only four rows of plates.

Allied to *Melonites* is the Carboniferous genus *Lepidesthes*, in which the ambulacra are composed of no less than ten rows of plates, the interambulacra being comparatively narrow and composed of six or seven rows of plates. The plates of the test, as in various other Palechinoids, are imbricated, the test thus becoming flexible, as it is in the recent genus *Asthenosoma*. The imbrication in the flexible Palechinoids differs from that of the *Echinothuridæ* in the fact that the overlapping of the interambulacral plates is from below upwards, and that of the ambulacral plates from above downwards, the reverse of this taking place in *Asthenosoma* and its allies.

A well-known Carboniferous genus is *Archæocidaris* (fig. 248), in which

the test is spheroidal, the ambulacra are only two-rowed, and the interambulacra are wide and are composed of three or more rows of plates. The interambulacral plates (fig. 248, *b*) carry each a large perforated tubercle, surrounded by a ring, supporting a long echinulate spine (*d*). As shown by Mr John Young, the test must have possessed a certain degree of flexibility, as the edges of some of the interambulacral plates are bevelled off. The Devonian and Carboniferous genus *Lepidechinus*

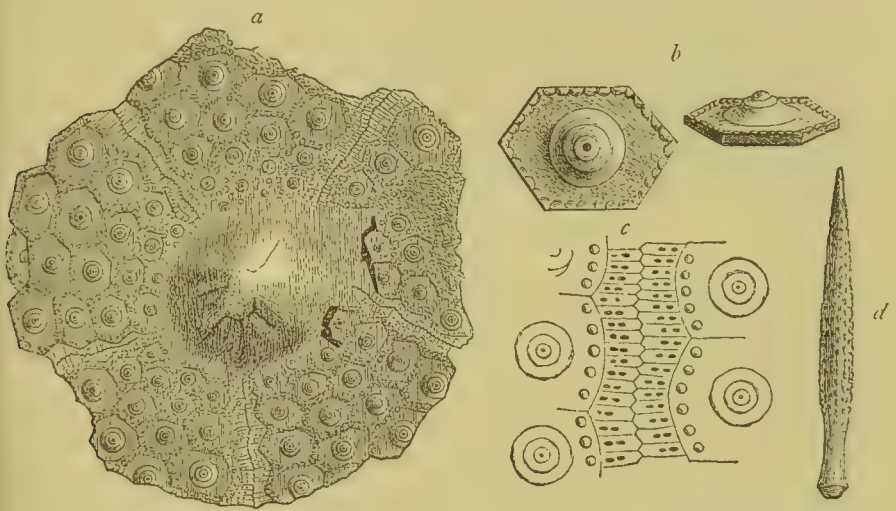


Fig. 248.—*Archæocidaris Wortheni*, from the Carboniferous Limestone of North America. *a*, Fragment of the under side, with the teeth, of the natural size; *b*, An interambulacral plate, viewed from above and sideways, showing the hexagonal form, and the spine-bearing tubercle; *c*, Portion of an ambulacrum, enlarged: *d*, One of the spines, of the natural size. (Copied from Zittel—after Hall.)

differs from the preceding in the fact that the plates of the test are strongly imbricated, the shell thus becoming quite flexible. The ambulacral areas are two-rowed, but the interambulacra have from nine to eleven rows of plates.

Differing in some respects from the preceding are the genera *Perischodomus*, *Rhoëchinus*, and *Lepidocentrus*, of which the two first are Carboniferous, while the last is found in the Devonian rocks. In all these genera, the test is rendered flexible by the overlapping of the interambulacral plates.

Lastly, the Triassic genus *Anaulocidaris*, known by detached plates and spines, is allied to *Archæocidaris*, and, so far as known, is the latest representative of the division of the Palechinoids.

Order II. Euechinoidea.

This division comprises all those Sea-urchins in which *both the ambulacral and interambulacral areas are constantly two-rowed, the test thus consisting of twenty rows of plates. The genital and ocular plates are almost always perforated by a single opening each; and a masticatory apparatus may be present or absent. The test may be "regular" or "irregular."*

The order of the Euechinoids includes all the normal Sea-urchins, and the distribution of the group in time is remarkable. No Euechinoid has hitherto been detected in any Palæozoic deposit anterior to the Permian, but a vast development of the forms of this division takes place in rocks of Mesozoic age, while all the Tertiary and Recent Urchins also belong to this group. In the Jurassic and Cretaceous rocks the Euechinoids attain their maximum development, and very numerous forms are also known from the Tertiary formations.

The *Euechinoidea* may be divided into the two sub-orders of the *Regulares* and *Irregulares*, the characters and chief groups of which will be briefly treated of in the following pages.

Regular Euechinoids.

The sub-order *Regulares* (*Echinoidea endocyclica*) includes all those Euechinoids in which the test is "regular," the mouth being inferior and central, while the anus occupies the centre of the superior surface, and is surrounded by the apical disc. The form of the test is usually spheroidal, and the ambulacral areas are perfect, and are all alike. The mouth is furnished with a masticatory apparatus. In *Tetracidaris* the interambulacra are in part four-rowed, but in all others they are two-rowed, as are the ambulacra in all cases. The members of this sub-order appear to be the most ancient forms of the Euechinoids, being tolerably well represented in the Trias, and even occurring in the still older Permian formation (*Eocidaris.*) They are largely represented in the Jurassic and Cretaceous formations, but begin to diminish in numbers in the Eocene Tertiary. The *Regulares* may be divided into the four principal families of the *Cidaridæ*, *Salenidæ*, *Echinothuridæ*, and *Glyphostomata*, the more important forms of which are noticed below.

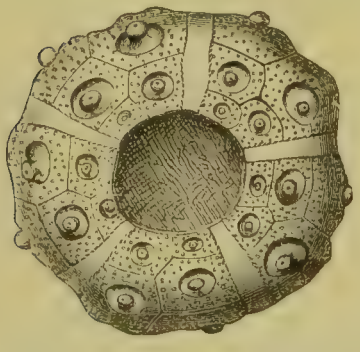


Fig. 249.—Under surface of the test of *Cidaris vesiculosa*, of the natural size. Chalk. (After Wright.)

Family 1. *Cidaridæ.*—In this family the test is spheroidal, and more or less flattened at the oral and anal poles. The ambulacral areas (fig. 249), are very narrow, often flexuous, and never provided with large tubercles. The interambulacral areas are wide, and carry large perforated tubercles, surrounded by an areola, and supporting the primary spines. The spines are of two sizes, the primary ones usually more or less cylindrical, clavate, or fusiform, and generally longitudinally ridged or tuberculate (fig. 242).

Of the genera of this family, *Cidaris* itself (fig. 249) is the most important, ranging from the Trias to the present day. *Rhabdocidaris* is Jurassic and Cretaceous; *Diplocidaris* is Jurassic; and the *Porocidaris* of the Secondary and Tertiary periods has now been detected by Sir Wyville Thomson in a living condition. In the aberrant Cretaceous genus *Tetracidaris*, the interambulacral zones are composed each of four rows of plates, reduced to two rows in the neighbourhood of the apex.

The genus *Eocidaris*, based upon a form which occurs in the Permian rocks of Germany, has been generally placed among the Palechinoids, in the vicinity of *Archæocidaris*. According to the recent researches of Kolesch, however, the interambulacral and ambulacral areas in *E. Keyserlingi* are two-rowed, and the genus is therefore properly referable to the Euechinoids. The Devonian and Carboniferous Urchins which have been referred to *Eocidaris* have more than twenty rows of plates in the corona, and must therefore be removed from this genus as now understood. With our present knowledge, therefore, the Permian *Eocidaris* must be regarded as the oldest type of the Euechinoids.

Family 2. *Salenidæ*.—In this family the test is generally spheroidal, hemispherical, or depressed, and the ambulacral areas are always narrow, sometimes straight, sometimes flexuous, and without large primary tubercles. The interambulacral areas are always provided with two rows of large tubercles, with crenulated bosses, which may or may not be perforated. The leading character of the family, however, is to be found in the apical disc (figs. 250 and 251), which is of unusually large size, and possesses a supernumerary or "suranal" plate in addition to the ten normal plates. This suranal plate (fig. 250, *s*) is placed in front of the anus, and it may be single, or it may be represented by several (not more than eight) elements. From a morphological point of view the suranal plate may be compared with the "dorso-central" plate of the Crinoids, while the genital and ocular plates respectively correspond to the basals and radials of the Crinoidal calyx. The "madreporite" is imperfectly developed, and often hardly recognisable. The peristomial membrane is furnished with calcareous plates which differ from the peristomial plates of the *Cidaridæ* in the fact that the rows of ambulacral pores are not continued over them to the mouth.

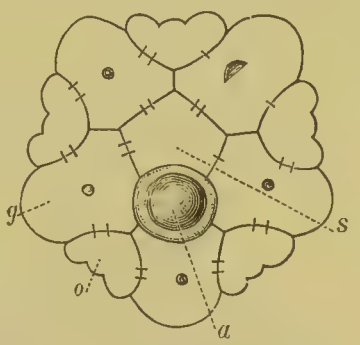


Fig. 250.—Apical disc of *Peltastes Wrightii*, one of the *Salenidæ*. *a*, Anus; *g*, One of the genital plates; *o*, One of the ocular plates; *s*, Suranal plate. Twice the natural size. Cretaceous (Lower Greensand). (After Wright.)

The genus *Salenia* itself (fig. 251) appears for the first time in the Cretaceous rocks, and still survives at the present day. *Peltastes*, with a similar range in time to *Salenia*, differs from the latter in the fact that

the anus is placed in the middle line ; and the *Goniophorus* of the Chalk is a closely allied form. *Acrosalenia*, again, ranges from the Lias to the Chalk.

Family 3. *Echinothuridæ.*—In this small but highly remarkable division of the *Echinoidea* the test is "regular," the anus being



Fig. 251.—*Salenia personata.* The left-hand figure represents the upper surface of the shell, and shows the anus surrounded by the apical disc. The right-hand figure shows the under side with the peristomial space.

placed in the centre of the apical disc, and the ambulacral areas being continuous ; but the plates of both the ambulacral and interambulacral areas are imbricated and overlap one another (fig. 252), the test thus becoming flexible. In this abnormal character, the *Echinothuridæ* agree with some of the Palæozoic Urchins, but they

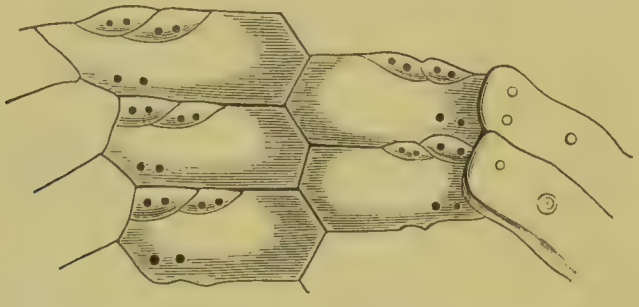


Fig. 252.—Portion of one of the ambulacral areas of *Echinothuria floris*, enlarged four times. Chalk. (After Wright.)

differ from these, and agree with the ordinary Regular Echinoids in having the test composed of no more than twenty rows of plates.

The only fossil forms of this group, as yet discovered, are referable to the Cretaceous genus *Echinothuria*, the true affinities of which have now been elucidated by the discovery of the extraordinary living types referred to the genera *Asthenosoma* and *Phormosoma.*

Family 4. *Glyphostomata.*—In this family the ambulacral areas are not much narrower than the interambulacral, and both as a rule carry primary tubercles. The peristomial membrane usually carries irregular calcareous ossicles, but is not completely plated, and the peristome is furnished with more or less marked incisions at its angles. "Auriculæ" are present. This family is divisible into the

two minor groups of the *Diadematidæ* and the *Echinidæ*, both of which appear in the Secondary period, and are represented at the present day.

In the *Diadematidæ*, the pairs of ambulacral pores (fig 253) form a single row on each side of the ambulacral areas, except near the apex and the peristome, where more than one row of pore-pairs may be developed. The test is generally circular or pentagonal,

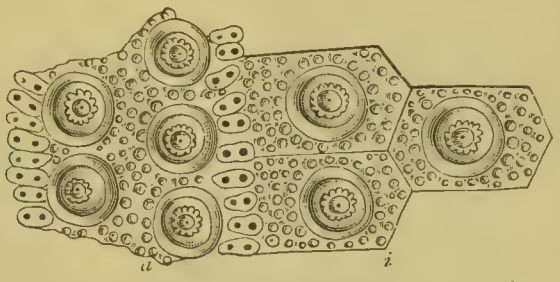


Fig. 253.—Portion of the test of *Pseudodiadema Fittonii*, enlarged four times. *a*, Ambulacral area; *i*, Interambulacral area. Lower Greensand (Cretaceous). (After Wright.)

more or less depressed and flat below. The ambulacral areas are wide, and carry two rows of large primary tubercles, equal in size to the two or more rows of tubercles upon the interambulacra. The tubercles are sometimes perforated, sometimes imperforate, and they may or may not be crenulated. The spines are cylindrical and slender, and usually of considerable length. In the living *Diadema* the spines are long, tubular, and covered with imbricated scales

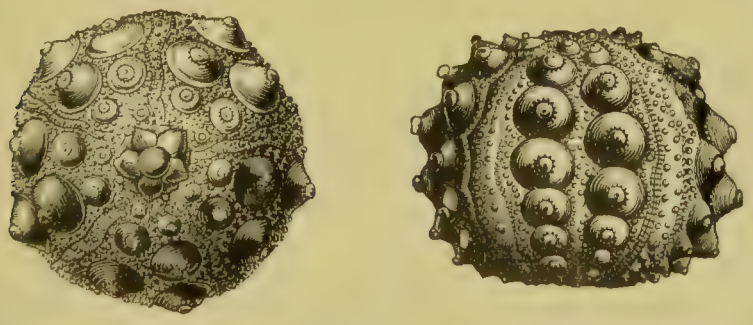


Fig. 254.—*Hemicidaris crenularis*, showing tubercles, the larger of which are perforated, and are surrounded by an areola. Jurassic.

arranged in oblique rings. The *Diadematidæ* are very extensively represented in the Secondary rocks, the earliest forms appearing in the Upper Trias; the Tertiary forms are less numerous, and a limited number of types referable to the group still exist.

Of the genera of this family, *Hemicidaris* (fig. 254) has a spheroidal, more or less depressed test, with a general resemblance to that of the

Cidaridæ. The ambulacral areas, however, though narrow and mostly undulated, are wider than in the *Cidaridæ*, and are provided with comparatively large tubercles, which may be developed inferiorly only (*Hemicidaris*), or which may extend along the entire length of the area (*Acrocidaris*). The interambulacral areas are wide, and carry very large perforated tubercles with crenulated bosses. The spines are usually long, cylindrical, and tapering. The type-genus of this family is *Hemicidaris* (fig. 254), which ranges from the Upper Trias to the Lower Cretaceous inclusive. In *Acrocidaris*, of the Jurassic and Cretaceous periods, the ambulacral areas are comparatively wide. In the genus *Pseudodiadema*, which ranges from the Lias to the Eocene Tertiary, the spines are solid and microscopically striated, and the tubercles are perforated (fig. 253). On the other hand, in the genus *Cyphosoma* and in a number of allied forms, the tubercles are imperforate. The species of *Cyphosoma* are mostly found in the Chalk, but some occur in the Eocene, and a single species survives at present. *Hemipedina*, again, which begins in the Jurassic rocks, and which is also represented at the present day by a single living species, is like *Pseudodiadema*, but the tubercles are not crenulated. This is also the case with the extensive genus *Goniopygus* (fig. 255), which is principally Cretaceous in its range, though also occur-



Fig. 255.—*Goniopygus major*, viewed from above and sideways, of the natural size. Cretaceous.

ring in the Eocene rocks. In the great size of the apical disc this genus reminds us of *Salenia*, but it wants the supernumerary "suranal" plate of the latter. Among the many other genera of this sub-family, *Cottaldia* (Chalk to Recent), *Glypticus* (Jurassic), *Codiopsis* (Cretaceous), and *Temnechinus* (Pliocene) may be specially mentioned; but the number of types included in this group is too large to permit of further particularisation.

In the sub-family of the *Echinidæ*, the general structure of the test is much the same as in the *Diadematidæ*, but the ambulacral plates consist of at least three "pore-plates" fused together, and the pairs of ambulacral pores are arranged in three or more rows (rarely in two rows only) on each side of each ambulacrum (fig. 256, *b*). The test is usually globular or hemispherical, and the ambulacral areas are comparatively wide, and carry two or more rows of tubercles. The interambulacral areas are wide, and carry primary tubercles, which are always imperforate, and are never of very large size. The spines are short and awl-shaped, and their surface is marked with fine longitudinal lines.

In many genera of the *Echinidæ* each ambulacral plate carries three pairs of pores, and types exhibiting this character appear as early as the Jurassic period. One of the leading genera thus characterised is *Stomechinus* (fig. 256), which is found in both the Jurassic and Cretaceous deposits. An allied Jurassic genus is *Polycyphus;* while *Salmacis* and *Echinus* proper begin in the Eocene Tertiary, and are represented at the present day by living species. On the other hand, in other genera of the *Echinidæ* each ambulacral plate carries more than three pairs of ambulacral pores. The forms of this group are comparatively modern, a few

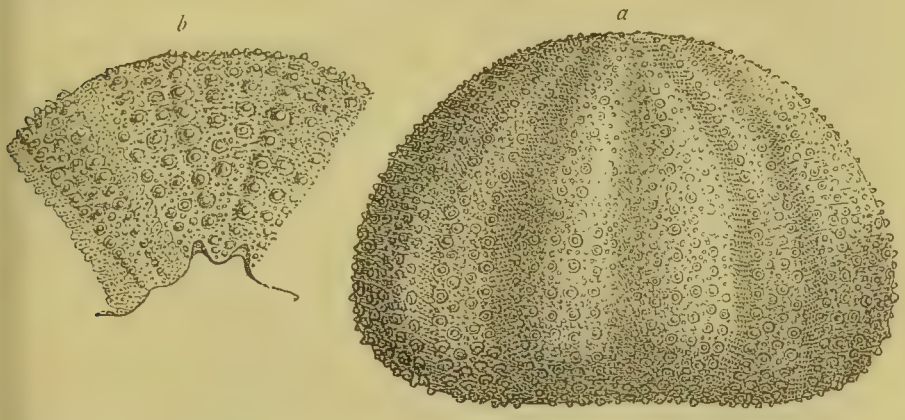


Fig. 256.—*Stomechinus lineatus*, from the Jurassic rocks (Coral Rag) of Germany. *a*, A specimen viewed in profile, of the natural size; *b*, Part of the oral region of the same. (After Zittel.)

types (*Phymechinus*, *Pedinopsis*, &c.) occurring in the Upper Jurassic or Cretaceous rocks, but the majority being Tertiary or Recent. The two most important members of this section are *Sphærechinus* and *Strongylocentrotus*, both of which begin in the Pliocene Tertiary, and are represented by living species.

Irregular Euechinoids.

The sub-order of the *Irregulares* (*Echinoidea exocyclica*) includes all those Euechinoids in which the test is "irregular," the anus being excentric, and not connected with the genital disc. The mouth is placed on the lower surface, and may be central or excentric in position, while a masticatory apparatus may or may not be present. The test is bilaterally symmetrical, commonly of an oblong, pentagonal, heart-shaped, or discoidal figure (as in the common "Heart-urchins" and "Cake-urchins"). There are commonly only four genital plates in the apical disc, and the ambulacra may be either simple or petaloid.

The Irregular Euechinoids have been divided into two groups, according as they possess a masticatory apparatus (*Gnathostomata*), or are without teeth (*Atelostomata*); but these two groups are very closely connected, and it seems that too much weight has been

attached to the value in classification of this particular character. Moreover, it has not in all cases been certainly ascertained whether or not a masticatory apparatus is actually present. Here, therefore, it will be sufficient to divide the Irregular Euechinoids into the six families of the *Conoclypeidæ*, *Clypeastridæ*, *Echinoconidæ*, *Cassidulidæ*, *Holasteridæ*, and *Spatangidæ*. The oldest types of the whole series (*Pygaster* and *Galeropygus*) appear in the Lias, and numerous forms are known in the later Mesozoic and Tertiary deposits, while the group is largely represented at the present day.

Family 1. *Conoclypeidæ*.—The Urchins of this family have a rounded or ovoid, gibbous test, covered with small tubercles and spines. The ambulacra are petaloid, but are continued inferiorly as far as the mouth. There are only four genital plates, and the madreporite is of large size. The mouth is placed in the centre of the inferior surface, and the anus is submarginal. Teeth are present, and "auricles" are also developed. All the members of this family

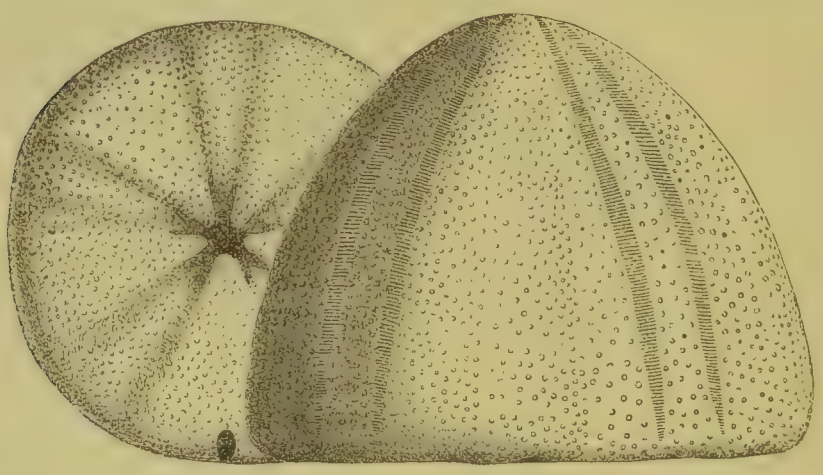


Fig. 257.—*Conoclypus conoideus*, from the Eocene rocks of Germany, viewed sideways and from below, reduced in size. (After Zittel.)

except one are referable to the single genus *Conoclypus* (fig. 257), the species of which range from the Chalk to the present day, being most abundant in the Eocene Tertiary.

Family 2. *Clypeastridæ*.—In this family the test is usually circular or elliptical, generally depressed, the surface covered with small tubercles surrounded by sunken, ring-like *areolæ*, and carrying hair-like spines. The dorsal portions of the ambulacral zones are wide and petaloid, and the ambulacral pores are confined to the apical "rosette" thus formed. The mouth is inferior, central, and armed with teeth; and the anus is marginal or infra-marginal. The madreporite occupies almost the whole of the apical disc, and the genital plates (four or five in number) are only indicated by their pores.

The interior of the shell, as a rule, is more or less subdivided by calcareous pillars or septa. The Clypeastrids range from the Chalk to the present day, but the early forms of the group are small.

The typical Clypeastrids have the test more or less gibbous superiorly, the two most important genera being *Echinocyamus* and *Clypeaster*. The first of these includes small oval Urchins, which range from the Chalk to the present day; while the latter (fig. 258) comprises large, massive, elliptical or pentagonal types, with a conspicuously developed ambulacral rosette.

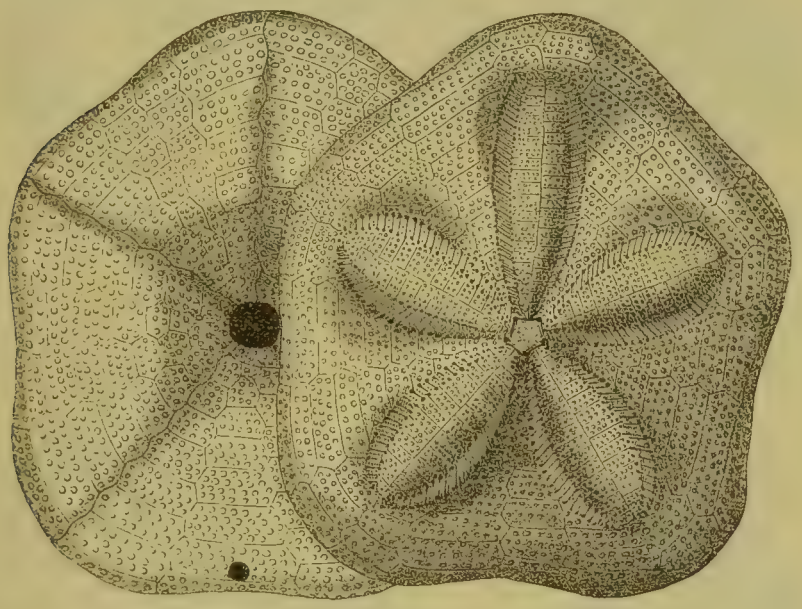


Fig. 258.—*Clypeaster grandiflorus*, from the Miocene Tertiary, viewed from above and below, slightly reduced in size. (Copied from Zittel, after Desor.)

The oldest known species of *Clypeaster* appear in the Eocene Tertiary, but there are numerous Miocene and Pliocene forms, and the genus is well represented in recent seas.

In another group of Clypeastrids, exemplified by such genera as *Scutella* and *Echinarachnius*, the test is so flattened as to become discoid or cake-like. The genus *Scutella* (fig. 240) is wholly confined to the Eocene and Miocene deposits, while the closely allied types placed under *Echinarachnius* are still represented in existing seas.

Family 3. *Echinoconidæ*.—In this family the test is usually circular or subpentagonal, the ambulacral areas being narrow, and running continuously from the apical disc to the peristome (fig. 259). Both the ambulacral and interambulacral areas carry small, crenulated, and perforated tubercles, which support short and awl-shaped spines. The mouth is inferior and central, and the excentric anus may be superior in position, but is usually inferior or marginal. There may be only four genital plates in the apical disc.

The position of the family *Echinoconidæ* has been rendered doubtful by the researches of Professor Martin Duncan, who has shown that the type-genus, *Echinoconus*, usually regarded as possessing teeth and "auricles," is really destitute of both these structures. In accordance with this, Dr Duncan would remove the genus *Echinoconus* to the family of the *Cassidulidæ*. The forms included in the family

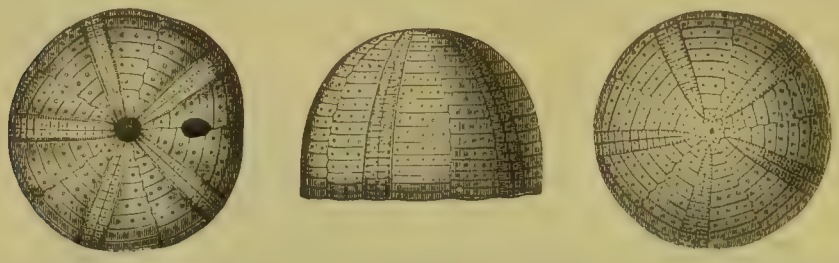


Fig. 259.—*Discoidea cylindrica*. The right-hand figure shows the summit of the shell, with the genital disc. The left-hand figure shows the base of the shell, on which are situated both the mouth and anus. Cretaceous.

Echinoconidæ are almost wholly confined to the Jurassic and Cretaceous rocks, so far as at present known; but a living species of *Pygaster* has been detected, and this genus, at any rate, must have representatives in the Tertiary rocks.

The genus *Echinoconus* (=*Galerites*) is exclusively confined to the Cretaceous rocks, *E. vulgaris* and *E. conicus* (=*Galerites albogalerus*) being very common species in the White Chalk. The test in this genus (fig. 239) is rounded or subpentagonal, often conical, with a nearly flat base. The anus is infra-marginal or nearly marginal. *Discoidea* (fig. 259) is also confined to the Cretaceous rocks, and is nearly related to the preceding, but the margins of the interambulacral areas in the interior of the test are strengthened by longitudinal thickenings or ribs. *Holectypus*, again, is closely allied to *Discoidea*, but the test is depressed (fig. 260), and there are no internal ribs. The species of this genus are Jurassic and Cretaceous. Lastly, in the genus *Pygaster* (fig. 261), the anal aperture is of great size, oblong or pyriform in shape, and situated on the superior aspect of the shell. All the five genital plates are present, and are perforated for the generative ducts. The species of this genus are mostly Jurassic and Cretaceous, but a recent species is known to exist.



Fig. 260.—Test of *Holectypus hemisphericus*, viewed from above—Jurassic. (After Edward Forbes.)

Family 4. *Cassidulidæ*.—This family comprises irregular Urchins in which the mouth is invariably edentulous, and is placed centrally or subcentrally on the inferior surface, while the anus is excentric, and is generally placed on the upper surface (fig. 262). The test is generally oval or elliptical, and the ambulacral zones are approxi-

mately similar, and may be either simple (*Echinonidæ*) or petaloid (*Echinolampadæ*). Only four genital plates are furnished with per-

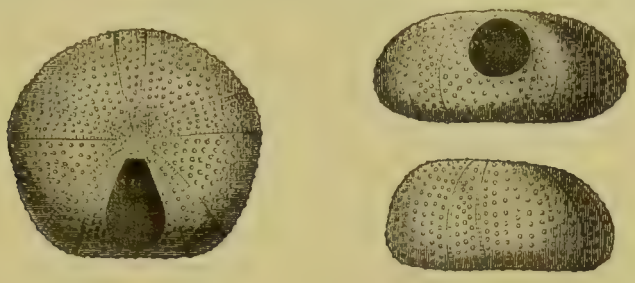


Fig. 261.—*Pygaster truncatus*, viewed from above, from behind, and from one side. Cretaceous.

forations for the generative ducts. The range of the family is from the Jurassic to the present day inclusive.

In one series of the *Cassidulidæ*—sometimes spoken of as the *Echinonidæ*—the ambulacra are simple and linear, and the mouth is central or



Fig. 262.—*Hyboclypus gibberulus*, viewed from above, from one side, and from below. Jurassic.

subcentral. A good example of this is the Jurassic genus *Hyboclypus* (fig. 262), in which the mouth is removed towards the anterior side, the anus is in a longitudinal dorsal valley, and the apical disc is elongated, so that the posterior two ambulacra become disjoined from the anterior three. Other examples of this group are the Cretaceous and Eocene genus *Pyrina*, and the Miocene and Recent genus *Echinoneus*. In another group of the *Cassidulidæ*—sometimes spoken of as the *Echinolampadæ*—the ambulacra are petaloid, and are generally sunk in the vicinity of the mouth in grooves separated by the swollen interambulacra, giving rise to a peristomial rosette or "floscelle." Some of the members of this group make a near approach to the preceding, being without a conspicuous oral rosette, and having ambulacra of a but very slightly petaloidal form; and these have sometimes been separated to form a distinct group (*Echinobrissidæ*). Of the many forms



Fig. 263.—*Echinobrissus clunicularis*, Jurassic, viewed from above. (After Wright.)

included in this group the genus *Echinobrissus* is one of the most widely distributed, species of the genus being very abundant in the Jurassic rocks, but extending also into the Cretaceous. In this genus (fig. 263), the test is concave below, and the anus is placed in a dorsal sulcus. Other well-known genera are *Nucleolites* (Chalk to Recent), *Pygurus* (Jurassic and Cretaceous), *Clypeus* (Jurassic), *Pygaulus* (Cretaceous), *Cassidulus* (Cretaceous and Tertiary), *Echinanthus* (Cretaceous and Tertiary), and the Tertiary and Recent *Catopygus* and *Echinolampas*.

Family 5. *Holasteridæ*.—This family comprises ovoid Urchins, with simple ambulacra, and a generally very gibbous test. The apical disc is usually drawn out in an antero-posterior direction, the elongation being sometimes so great that the two posterior ambulacra



Fig. 264.—*Collyrites* (*Dysaster*) *Eudesi*, viewed from above, from one side, and from below. Jurassic.

are widely separated from the three anterior ones on the summit of the shell (fig. 264). The peristome is excentric, generally oblique or bilabiate; and the anus is inframarginal or marginal. The members of this family are mostly Jurassic and Cretaceous, but a number of recent forms are known to exist.

In one group of this family (the *Collyritidæ* of D'Orbigny, or the *Dysasteridæ* of other writers), the apical disc is greatly elongated, and the narrow ambulacral areas thus become more or less "disjunct," the two hinder ambulacra meeting superiorly at one end of the disc, while the three anterior ambulacra meet at the other end of the same. The principal genus of this group is *Collyrites* itself (figs. 264 and 265), in which the test is oval or somewhat heart-shaped, the mouth being inferior and excentric, and the anus being supramarginal. The elements of the apical disc are detached from one another, the anterior portion containing four perforated genital plates and three ocular plates, while the posterior portion, connected with the preceding by a narrow series of supernumerary plates, contains the two other ocular plates. The genus is represented by numerous species in the Jurassic and Cretaceous rocks. Closely allied to the preceding, and with a similar geological range, is the genus *Dysaster*.



Fig. 265.—Upper surface of the test of *Collyrites elliptica*, showing long apical disc and disjunct ambulacra. Jurassic. (After Zittel.)

In another series of the *Holasteridæ*—sometimes spoken of as the *Ananchytidæ* or *Echinocoridæ*—the apical disc may be either elongated or compact, but in either case the five ambulacra all meet in it. The chief genus of this group is *Ananchytes* (fig. 266) itself, in which the test is ovate, and highly convex above, the peristome is advanced forwards and is two-lipped, and the anus is inframarginal. The species of this genus are confined to the Chalk, the commonest form being the well-known and highly variable *A. ovata*. The genus *Holaster* is nearly related to *Ananchytes*, but the test is sub-cordate, the apical disc is more elongated, and the anus is marginal or supramarginal. The species are chiefly Cretaceous, but are found in the Tertiary deposits in Australia. In *Cardiaster*, again, which is also Cretaceous, there is the additional character of the existence of a "fasciole," which passes beneath the anus and is continued on the sides of the test. As will be seen immediately, the presence of "fascioles"—that is to say, of circumscribed bands of microscopic granules, occupying definite areas and positions on the test—is highly characteristic of the *Spatangidæ*, towards which *Cardiaster* thus makes an approach.



Fig. 266.—Under surface of the test of *Ananchytes ovata*, showing the position of the mouth and anus. Jurassic. (After Forbes.)

Family 6. *Spatangidæ*.—In the members of this family—often spoken of as "Heart-urchins"—the test is markedly bilateral, and is usually conspicuously heart-shaped (fig. 267). The mouth is advanced far forwards on the under side, and the anus is supra-marginal, and is placed in the posterior interambulacrum. The ambulacra are petaloid, and the unpaired anterior ambulacrum always differs more or less from the others, being usually lodged in a groove or "sulcus" (fig. 267). The mouth is typically bilabiate, but is in some cases five-sided;

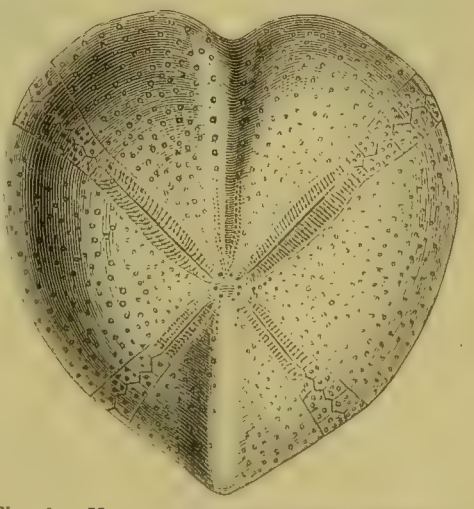


Fig. 267.—Upper surface of *Micraster coranguinum*. Cretaceous. (After Forbes.)

and, as in the preceding two families, teeth are invariably wanting. The tubercles of the test are mostly small, and carry hair-like spines; but there are larger, crenulated, and perforated tubercles for the support of larger spines. As a rule, bands of microscopic tubercles known as "fascioles" (fig. 268) are present, and occupy different positions in different genera. Sometimes the "fasciole" surrounds the ambulacral rosette, when it is said to be "peripetalous"; sometimes it is "internal," surrounding the unpaired ambulacrum; sometimes it surrounds the sides, and is said to be "lateral"; at other times it runs round the test, and is termed "marginal"; and, lastly, it may be limited to the base of the anal aperture, when it is termed "sub-anal."

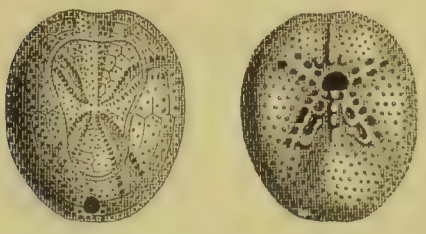


Fig. 268.—*Gualteria Orbignyana*, viewed both from above and below. The left-hand figure shows the "fasciole" cutting the ambulacral rosette. Eocene.

Of the genera of *Spatangidæ* characterised by a pentagonal mouth, the chief is *Toxaster*, the species of which are wholly Cretaceous. Of the more normal Heart-urchins, with a bilabiate mouth, *Micraster* (fig. 267) possesses a sub-anal fasciole, and is widely distributed in the Chalk, the genus being also represented in the Tertiary rocks of Australia. *Epiaster*, likewise found in the Chalk, has no sub-anal fasciole, but is otherwise similar to *Micraster*. *Hemiaster*, very abundant in the Cretaceous period, but also represented by Tertiary and living species, has a peripetalous fasciole. *Linthia* (*Periaster*) has both a peripetalous and a lateral fasciole, and ranges from the Chalk to the present day. *Gualteria* and *Macropneustes* are Eocene types; while *Schizaster*, *Brissus*, *Brissopsis*, *Echinospatagus* (*Amphidetus*), *Eupatagus*, and *Spatangus* are well-known Tertiary and Recent genera.

CHAPTER XXIV.

ASTEROIDEA, OPHIUROIDEA, AND HOLOTHUROIDEA.

Class II. Asteroidea.

The class *Asteroidea* comprises the ordinary Star-fishes, and is defined by the following characters: *The body* (fig. 269) *is star-shaped or pentagonal, and consists of a central body or "disc" sur-*



Fig. 269.—*Astropecten irregularis*, viewed from the upper surface; *m* Madreporite. Recent.

rounded by five or more lobes ("*arms*," *or* "*rays*"), *which radiate from the body, are hollow, and contain prolongations of the viscera.* The body is not enclosed in an immovable box, as in the *Echinoidea*, but *the integument* ("*perisome*") *is coriaceous, and is strengthened by*

irregular calcareous plates, or studded by calcareous spines. No dental apparatus is present. The mouth is inferior, and central in position; the anus either absent or dorsal. The ambulacral tube-feet are protruded from grooves on the under surface of the rays.

In their form the Star-fishes differ considerably, though in most the figure is markedly stellate. The animal consists of a central body or "disc," which gives off radiating processes or "arms," but the size of the disc is very different in different species, and the arms vary greatly in length and in number. In many living and extinct forms the "disc" is inconspicuous, and appears to be formed simply by the junction of the bases of the arms, which in this case are normally five in number. The living *Asterias* and *Cribrellæ*, and the extinct *Palæasters* (fig. 270), may be taken as examples of this state of parts. In other forms, as in the Sun-stars (*Solaster*) and the extinct *Lepidasters* and *Plumasters*, the disc is very broad, exceeding or equalling the length of the arms in its diameter; whilst the rays vary in number, from eight or ten up to thirty or more. In the Cushion-stars (*Goniaster* and *Goniodiscus*), again, the body is pentagonal, disc-shaped, and flattened on the two sides, and the arms can only be recognised by the ambulacral grooves on the lower surface (fig. 271).

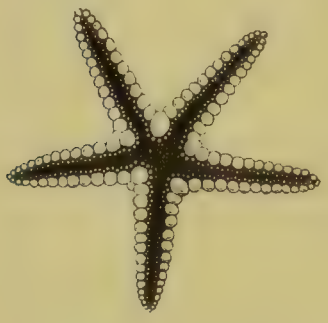


Fig. 270.—*Palæaster Niagarensis*, Hall. Ordovician.

On the upper surface of the body, placed nearly in the centre of the disc, is the minute aperture of the anus, when this is present; but the genera *Astropecten*, *Ctenodiscus*, and *Luidia* are destitute of a vent. Also on the upper surface is the "madreporite" or "madreporiform tubercle," in the form of a spongy or striated disc placed at the angle of junction of two rays. It has the same function as in the Echinoids, serving to protect the entrance to the water-vascular system. Ordinarily there is a single madreporiform tubercle, but in some genera there are two, three, or more tubercles; and there seems in some cases to be a correspondence between the number of the arms and the number of madreporic plates.

Placed in the centre of the lower surface is the mouth, at the angles of which are five pairs of so-called "oral plates" (fig. 271, *o*), which must not be confounded with plates similarly named in the Crinoids; but there are no teeth. Deep furrows, known as the "ambulacral grooves," radiate from the mouth, one along the under surface of each of the arms, gradually narrowing as the extremity of the latter is approached. The roof of each groove is constituted by a double row of minute calcareous pieces—the "ambulacral ossicles"

—which are movably articulated to one another at their inner ends. Running in the roof of the groove, below the line of union of the two rows of ambulacral ossicles, is one of the radiating ambulacral vessels, from which are given off the rows of suctorial "tube-feet."

The integumentary skeleton of the Asteroids is less developed than in the Echinoids, and has the form of innumerable small calcareous pieces, or "ossicles," united together so as to form a species of chain-armour. The ossicles are generally united with one another in a reticulated manner, and the interspaces between them are filled by the coriaceous integument; but they may be directly united by their edges. In many genera a specially developed series of ossicles forms a row of plates, known as the "adambulacral plates" (fig. 271, *b*), on each side of the ambulacral furrows. In many genera, also, there is a single or double row of large plates, known as the "marginal plates" (fig. 271, *m*), round the margins of the disc and arms, along the line separating the dorsal and ventral surfaces. Spines are commonly developed, especially along the margins of the ambulacral grooves, but these structures are in no case movably articulated. The so-called "pedicellariæ" of the Asteroids, as in the Echinoids, may be regarded as peculiarly modified pincer-like spines; but the size of these is too small to render it likely that they can be commonly preserved in the fossil condition. In some genera (as in *Solaster*, *Luidia*, *Ctenodiscus*, &c.), there are large spines the summits of which carry bunches or tufts of minute calcareous processes, and which are known as "paxillæ." In other cases, as in *Pentaceros*, there are very much thickened spines, which may assume considerable dimensions. It is not improbable that the Ordovician fossils upon which the genus *Bolboporites* has been founded, are really of the nature of dermal spines belonging to some Asteroid like *Pentaceros*.

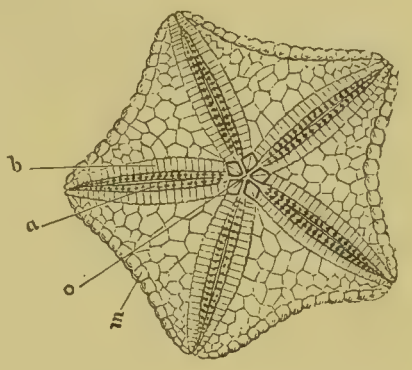


Fig. 271.—Diagram of a Star-fish (*Goniaster*), showing the under surface, with the mouth and ambulacral grooves. *a*, Ambulacral ossicles, with the ambulacral pores between them; *b*, Adambulacral plates, bounding the ambulacral grooves; *m*, Marginal plates (wanting in many species); *o*, Oral plates, placed at the angles of the mouth.

The ambulacral system of the Asteroids is essentially similar in its arrangement to that of the Echinoids. The external opening of the water-vessels is always placed interradially, between the two posterior rays (when five rays are present), and is provided with a porous "madreporite," two, three, or more of these being occasionally present. The madreporite admits the water to the short

"sand-canal," which opens into the circular vessel surrounding the gullet. From the circular canal arise radiating ambulacral vessels, which correspond in number with the number of the arms, and which are lodged, along with the radiating nerves, in deep "ambulacral grooves" on the under surface of the arms. Each radiating vessel gives off two or four rows of cylindrical tube-feet or "pedicels," the ends of which are usually sucker-like, and which are used in locomotion. The tube-feet are protruded by means of vesicles or "ampullæ," which spring from their bases, and are situated superiorly to the radiating vessel. As compared with the Echinoids, the essential peculiarity of the ambulacral system is that the radiating ambulacral vessels are situated externally, and are not covered over by a calcified integument. There are, therefore, no structures in the Asteroids which can be compared with the perforated ambulacral plates of the Sea-urchins, and the tube-feet of the former do not pass through any portion of the integumentary skeleton on the way to the surface. On the other hand, the radiating ambulacral vessels of the Star-fishes are protected by an *internal skeleton*, which is not present in the Echinoids, or which is only imperfectly represented in some types of the latter by the so-called "auriculæ." This internal skeleton has the form of a double

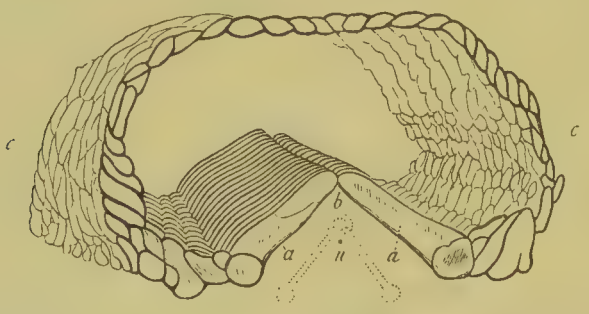


Fig. 272.—Diagrammatic section of the ray of *Asterias rubens*. *a a*, Ambulacral ossicles; *b*, Position of the ambulacral vessel; *c c*, Plates of the external skeleton; *n*, Nerve-cord. The dotted lines show the tube-feet proceeding from the ambulacral vessel, but the ampullæ are not represented.

series of elongated calcareous plates, the so-called "ambulacral ossicles," which form the roof of the ambulacral groove on the under side of each arm, and are so apposed to one another as to form a kind of elongated pent-house, beneath which is placed the radiating ambulacral vessel (fig. 272, *a a*). The ambulacral ossicles on the one side of the ambulacral groove may be directly apposed to the ossicles of the corresponding row on the other side of the groove (as in the typical Star-fishes), or the ossicles of the one row may alternate with those of the opposite row (as in the ancient group of the *Encrinasteriæ*). In either case the ambulacral ossicles are

so excavated on their sides as to give rise by their apposition laterally to a series of pores, by means of which the ampullæ communicate with the bases of the tube-feet. Hence, the ampullæ are situated in the interior of the arms, *superiorly* to the chain of ambulacral ossicles, while the radiating ambulacral vessels and tube-feet are placed *inferiorly* to the same.

In addition to these ambulacral vessels, Star-fishes possess a system of respiratory organs which are known as the dermal branchiæ or "papulæ." These are delicate cæcal processes of the integument, the cavities of which are in direct relationship with the general body-cavity. In one order of recent Star-fishes (*Phanerogonia*) they are restricted to the dorsal surface, while in the *Cryptogonia* they are distributed over the whole body.

The generative organs of the *Asteroidea* are situated within the "arms," above the chain of ambulacral ossicles, and they discharge their products by means of minute sieve-like openings in the angles between the arms, the size of these apertures being too small to admit of their recognition in a fossil condition.

The living Asteroids have a wide range in space, being principally shallow-water forms, but extending from the littoral zone to great depths in the sea. As regards their *distribution in time*, the Star-fishes are a group of great antiquity, the earliest members of the order appearing in the Ordovician (Upper Cambrian?) strata. Most of the Palæozoic types are peculiar, but the recent genus *Astropecten* is stated to occur in rocks as old as the Devonian.

As regards their *classification*, the Asteroids may be divided into two primary groups, or sub-classes, according to the arrangement of the ambulacral ossicles. In one great group (*Euasteroidea*), the two rows of ambulacral ossicles which roof over each ambulacral furrow are placed opposite to each other. The forms of this group are not unrepresented in the Palæozoic rocks, but they are principally characteristic of the Secondary and Tertiary deposits, and are the only types now in existence. On the other hand, most of the Palæozoic Star-fishes belong to the series of the *Encrinasteriæ*, in which the two rows of ambulacral ossicles in each arm are so placed as to alternate with one another. No form belonging to this group of Star-fishes appears to have survived the Palæozoic period. Owing to their rare occurrence as fossils, and their generally imperfect state of preservation, Star-fishes are not of special interest to the palæontological student, and it will be sufficient here to briefly indicate the chief characters of some of the more important of the known fossil forms.

The section of the *Encrinasteriæ*, in which the ambulacral ossicles are alternately placed, is, as above remarked, exclusively Palæozoic, and the widely distributed genus *Palæaster* may be taken as its

central type. In this genus (fig. 273) the body is five-armed, the disc being very small; and the ambulacral grooves on the under side of the arms are furnished with two rows of alternately placed ambulacral ossicles, bounded on each side by a row of "adambulacral plates," which are, in turn, bordered by a series of large "marginal" plates. On the dorsal surface are three or more rows of plates which are united by intermediate ossicles, and do not appear to be separated by intervening pores. The genus *Palæaster* comprises some species of considerable size, and ranges from the Ordovician to the Carboniferous. The Ordovician genus *Urasterella*

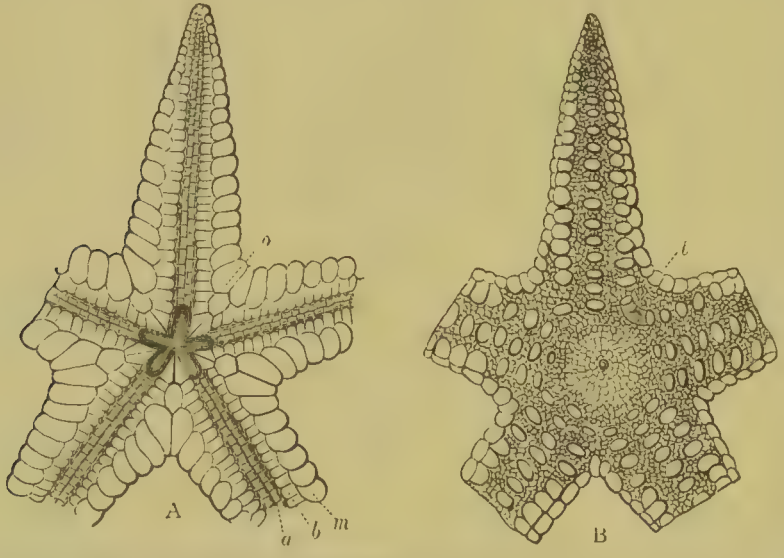


Fig. 273.—*Palæaster eucharis*, Devonian (after Hall). A, Under side of a specimen, four of the arms being cut short; B, Upper side of the same. *a*, Ambulacral ossicles, lying in the ambulacral grooves; *b*, Adambulacral plates; *m*, Marginal plates; *o*, One of the oral plates; *t*, Madreporiform tubercle.

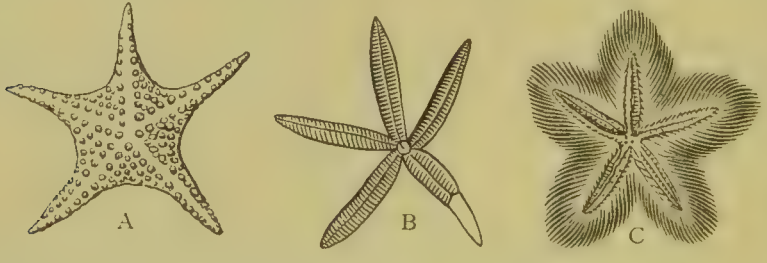


Fig. 274.—A, *Palasterina primæva*, Silurian; B, *Palæaster Ruthveni*, Silurian; C, *Palæocoma Colvini*, Silurian. (After Salter.)

(= *Stenaster*) is in many respects like *Palæaster*, but the ambulacral grooves are bordered by a row of adambulacral plates, without a second row of marginal plates. *Petraster*, also Ordovician, has an incomplete series of disc-plates between the adambulacral and mar-

ginal rows of plates, but is doubtfully separable from *Palæaster;* while the Ordovician and Silurian *Palasterina* (fig. 274, A) has the disc still more extensively developed, and is further distinguished by the fact that the plates of the adambulacral series which are placed at the angles of the oral aperture are large and triangular. The Silurian genus *Palæodiscus*, again, has a discoid form, the body being pentagonal, without distinct arms, and the mouth being furnished with five pairs of triangular oral plates. Lastly, the Silurian genus *Palæocoma* (fig. 274, C) is an aberrant form of this group, with slightly prominent arms, laterally bordered by long spines, the intervals between which are filled up by a netted membrane.

In the Devonian rocks, various forms of the *Encrinasteriæ* have been detected, the chief genus in this formation being *Aspidosoma*, in which the disc is of large size, with five small arms, and the structural characters are in many respects peculiar. Thus, the arms are covered superiorly with two or four rows of closely apposed plates, which are continued over the disc, leaving a central star-shaped space apparently covered only by a leathery skin; while the madreporite is stated to be placed interradially on the under side near the mouth. The known species of this singular genus are found in the Devonian rocks of Germany. *Helianthaster*, of the Devonian rocks of Germany and Britain, is imperfectly known, and may possibly be an Ophiuroid. It has a large disc, and from fourteen to sixteen arms.

The sub-class of the *Euasteroidea* is distinguished from the preceding by the fact that the pairs of ambulacral ossicles are placed opposite to each other, and are directly united by their inner ends. The members of this group appear in rocks as ancient as the Devonian, while all the Mesozoic, Kainozoic, and Recent Star-fishes are referable to this series.

The following classification of the *Euasteroidea* has recently been proposed by Sladen, some of the less important families being omitted :—

ORDER I. PHANEROGONIA.—Marginal plates large and well developed; papulæ restricted to the dorsal surface. Ambulacral plates well spaced; tube-feet in two rows.

Families.—Porcellanasteridæ (*Porcellanaster, Ctenodiscus*), Astropectinidæ (*Astropecten, Luidia*), Pentagonasteridæ (*Astrogonium, Stellaster, Goniodiscus*), Antheneidæ (*Goniaster*), Pentacerotidæ (*Pentaceros*).

ORDER II. CRYPTOGONIA.—Marginal plates inconspicuous; papulæ distributed over the whole body. Ambulacral plates crowded and narrow; tube-feet in two or four rows.

Families.—Solasteridæ (*Solaster, Crossaster*), Pterasteridæ (*Pteraster, Hymenaster*), Echinasteridæ (*Echinaster, Cribrella*), Asteriidæ (*Asterias*), Brisingidæ (*Brisinga*).

The forms of the *Euasteroidea* which have been detected in the Devonian rocks belong mostly to extinct genera (*Xenaster, Eoluidia,*

and *Palastropecten*), but the still existing genus *Astropecten* (*Asterias* of many authors) is represented by a single species (Stürtz), and the same genus is said to occur in the Carboniferous rocks. If some doubt attaches to the Palæozoic forms which have been referred to *Astropecten*, unquestionable remains of species of this genus occur in the Mesozoic and Tertiary rocks, the earliest appearing in the Lias. The genus belongs to the group of Star-fishes (*Phanerogonia*) in which the tube-feet are in two rows and the "papulæ" confined to the dorsal surface, and is recognised by its five-rayed form, and flattened disc and arms, the edges of which carry a double row of large "marginal plates" (figs. 269 and 275). The lower of the two

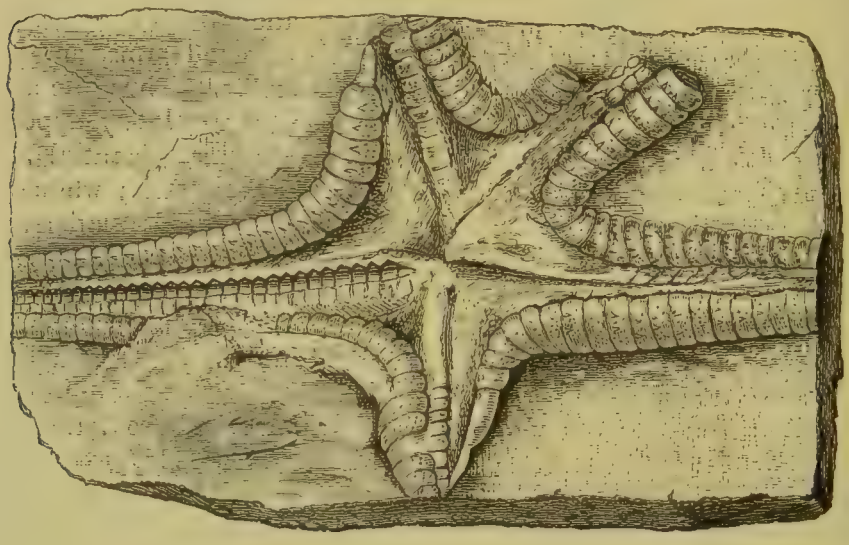


Fig. 275.—Under surface of *Astropecten Phillipsii*, of the natural size. Jurassic. (After Wright.)

rows of marginal plates is furnished with spines, and the whole of the upper surface is covered with tubercles crowned by groups of minute prickles.

Other genera of *Phanerogonia* which are abundantly represented in the Jurassic, Cretaceous, and Tertiary rocks, and which still survive, are *Goniaster*, *Astrogonium*, *Goniodiscus*, and *Stellaster*. The first-named genus comprises the so-called "Cushion-stars," and is characterised by the fact that the body has the form of a pentagonal disc (fig. 271), in which the arms are principally recognisable by the presence of the ambulacral furrows on the inferior surface. The disc is bordered by a double row of large "marginal plates," and the upper and lower surfaces are covered with small, four-sided or polygonal plates. Besides the above, the existing genera *Pentaceros* (*Oreaster*) and *Luidia* appear in the Jurassic, though the occurrence of the latter is not certainly established. Among the *Crypto-*

gonia, the recent genus *Solaster*, comprising the familiar "Sun-stars," is represented by a single known Jurassic species, and is easily recognised by its wide disc and short arms, and by the fact that the dorsal integument is studded at intervals with prominent "paxillæ." Another still living genus, which is known to have existed in rocks as old as the Lias, is *Asterias* (or *Uraster* of many authors). This familiar genus belongs to the group of Star-fishes in which the ambulacral tube-feet are in four rows, and is the only form of this group which has hitherto been found fossil. The disc is small, and the arms are long, and are variable in number, while the dorsal integument is hardened by netted ossicles, many of which are developed into projecting tubercles or blunt spines. The extinct genera of Mesozoic Star-fishes, such as the Jurassic *Plumaster* and *Tropidaster*, do not exhibit any special peculiarities demanding notice here.

Class III. Ophiuroidea.

The class of the *Ophiuroidea* comprises the small but familiar group of the "Brittle-stars" and "Sand-stars," and is characterised by the fact that *the body is stellate, consisting of a central "disc," in which the viscera are contained, and of elongated "arms," which are sharply separated from the disc, do not contain prolongations of the alimentary canal, and are not furnished inferiorly with open ambulacral grooves.*

The body in the Ophiuroids always has the form of a rounded or pentagonal disc (fig. 276), and carries long slender arms, which are typically simple, though they are branched in many of the Euryalids, and which are essentially employed as locomotive and prehensile organs. The arms do not contain diverticula from the alimentary canal, but they lodge the radiating ambulacral vessels and nerve-cords, these structures not being situated in open "ambulacral grooves," as in the Asteroids, but being covered in by the coriaceous or plated integument. On the under side of the body, in the centre of the disc, is seen the stellate opening of the mouth (fig. 276, c); and the reproductive organs open also on the under side by ten fissures or slits, a pair of these being situated at the base of each of the five arms. Owing to the absence of an anus, there is no aperture on the upper surface of the body.

With regard to the integumentary skeleton of the Brittle-stars, it is impossible to enter here into the interesting features shown in the embryonic condition of certain Ophiuroids, at which stage it can be shown that the exoskeleton of the dorsal surface is in many respects homologous with the apical disc of the Echinoids and the calyx of the Crinoids. In the adult condition, the integumentary skeleton of the Ophiuroids is of a very complicated character; but the im-

portance of the group from a palæontological point of view is not sufficient to justify its being treated of here except as regards its general features. The upper surface of the disc of an Ophiuroid is covered throughout with calcareous plates, scales, or granules. A large central plate ("dorsocentral") is sometimes recognisable, and a pair of large plates ("radial shields") is usually developed on the dorsal aspect of the disc at the point of origin of each of the

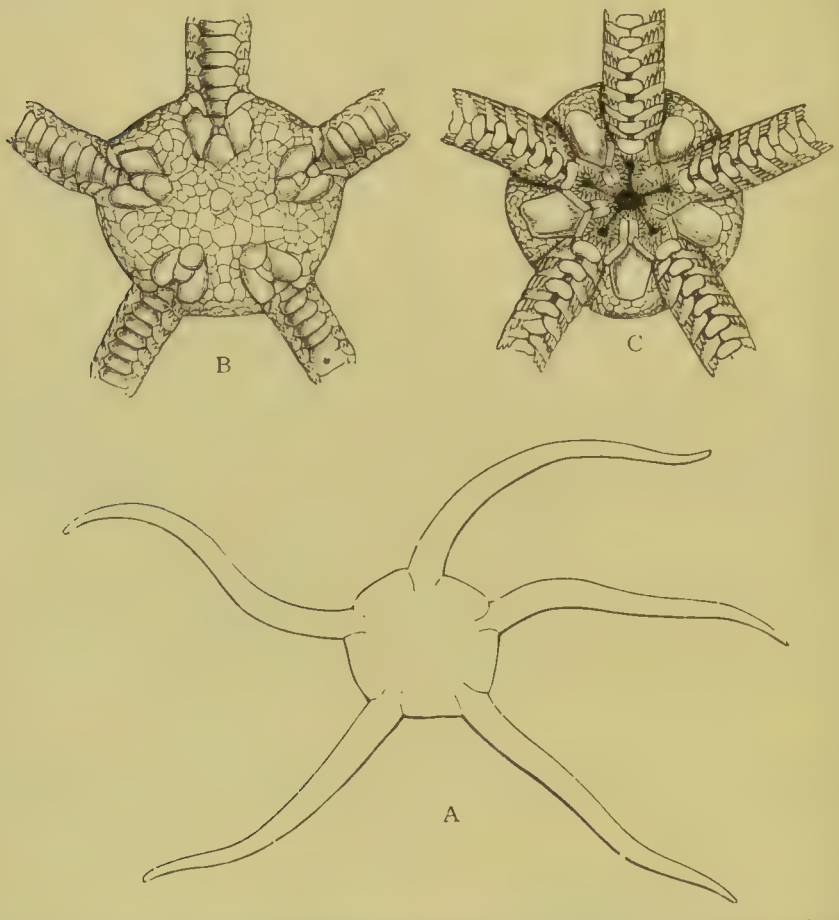


Fig. 276.—Ophiuroidea. *Ophioglypha lacertosa*. A, Outline, of the natural size; B, The disc viewed from above, twice the natural size; C, The disc viewed from below, showing the mouth and genital fissures, twice the natural size. (Original.)

five arms (fig. 276, B). On the under side of the disc the arms, with their ventral rows of plates, are continued to the mouth, but the spaces between the arms ("interbrachial areas") are covered with plates, scales, or minute tubercles of lime (fig. 276, C). The stellate aperture of the mouth is bordered with a system of peristomial ossicles, some of which act as teeth; while at its angles, one in each interbrachial space, are situated five large "mouth-shields"

(fig. 276, c), which are homologous with the "oral plates" of the Crinoids. In the majority of the Brittle-stars one (or more) of the oral plates is enlarged, and represents in function the "madreporite" of the Star-fishes.

The arms are, typically, protected by four rows of calcareous plates, one dorsal, one ventral, and two lateral (fig. 277). The lateral, or "adambulacral," plates carry rows of spines, and not only cover the sides of the arm, but also encroach upon the inferior surface. The ventral shields ("superambulacral plates") are so related to the lateral plates, that a pair of pores is formed on each side of each of the former, by means of which the tube-feet gain the exterior. In the Euryalids, the arms are covered with a leathery skin, containing minute granules and scales.

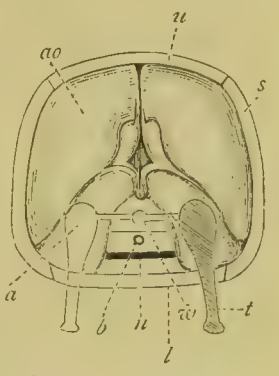


Fig. 277.—Diagram of the cross-section of the arm of an Ophiuroid (slightly altered from Sladen). *ao*, Ambulacral ossicle, immovably united with the corresponding ossicle of the opposite side; *u*, Superior plate of the arm; *s*, Lateral plate; *l*, Inferior plate; *n*, Radial nerve-cord; *b*, Radiating blood-vessel; *w*, Radiating ambulacral vessel; *t*, Tube-foot; *a*, Ampulla.

In addition to the proper integumentary skeleton, the Ophiuroids possess an *internal* or ambulacral skeleton, consisting of a linear series of large calcareous discs or "vertebral ossicles," which occupy the greater part of the interior of each arm, and are grooved inferiorly for the reception of the ambulacral vessel and radial nerve (fig. 277). These discs correspond with the "ambulacral ossicles" of the Star-fishes, but the ossicles of each pair are anchylosed with one another. Successive vertebral discs are movably articulated with one another, and the entire series is largely supplied with muscles. The first two pairs of ambulacral ossicles in each series have their lateral elements disjunct, instead of being fused in the middle line, the pieces of the first pair taking part in the formation of the calcified peristome, and thus becoming connected with the armature of the mouth.

The ambulacral system of the Ophiuroids is constructed upon essentially the same type as in the Asteroids and Echinoids, but its place as a locomotive apparatus is taken by the arms, the tube-feet being tentacle-like, without terminal suckers, and with no specially developed "ampullæ." The special peculiarity of the ambulacral system in the Ophiuroids, as compared with that of the Asteroids, is that the grooves on the under side of the row of ambulacral ossicles, in which lie the radiating ambulacral vessels, are not open, as they are in the latter, but are closed in by the passage over them of the integument. Another peculiar feature, in all except the extinct *Protophiurida*, is the position of the "madreporite" on the inferior

surface of the body and its connection with the oral plates, with one of which it is generally confluent.

As regards the digestive system, the Ophiuroids differ from the majority of the Asteroids in the fact that the alimentary canal terminates blindly, and there is, therefore, no anal aperture upon the dorsal surface of the disc.

Lastly, as regards the reproductive system, the generative glands in the Ophiuroids are placed interradially, and their ducts open into singular folded pouches or "bursæ," which in turn communicate with the exterior by means of slit-like openings (the "genital fissures"), which are placed, singly, or rarely in pairs, on the sides of the arms inferiorly, at their junction with the disc (fig. 276, c). Calcareous plates are sometimes developed in the walls of these bursæ, and currents of sea-water flow in and out of the genital fissures. It is probable, therefore, that these "genital bursæ" are partly respiratory in function, and that they correspond with the so-called "hydrospires" of the Cystoids and Blastoids.

The living Ophiuroids are all inhabitants of the sea, and the marine deposits of almost all the great geological periods have yielded examples of the group, the oldest known forms occurring in Ordovician strata. Most of the remains of Ophiuroids, and particularly those of the more ancient formations, are, however, more or less imperfect, while fossils of this group are, as a rule, exceedingly rare. It will be sufficient here, therefore, to deal with the fossil forms of Ophiuroids very briefly.

The existing Ophiuroids fall naturally into two sections—the *Euryalida* and *Ophiurida*—the characters of which are sufficiently distinct. In the *Euryalida*, the arms may be simple, but are more usually branched, and in either case their integument is leathery, the arms being devoid of the rows of plates so characteristic of the typical Brittle-stars. The type of this group is the genus *Astrophyton* (*Euryale*), comprising the well-known "Medusa-head Stars," characterised by their much-branched arms. The only two extinct genera which appear to be referable to the *Euryalida* are *Eucladia* and *Onychaster*. The former of these is found in the Silurian rocks of Britain, and is characterised by the possession of a granulated disc and of five bifurcating arms. The genus *Onychaster* (fig. 278) is based upon forms found in the Carboniferous Limestone of North America, and is characterised by the possession



Fig. 278.—*Onychaster flexilis*, viewed sideways, of the natural size, with the arms rolled up. From the Carboniferous Limestone of Indiana. (After Meek and Worthen—copied from Zittel.)

of a small disc, and of five simple round arms, which are covered with a granulated integument, and carry spines on their ventral aspect. As in the living Euryalids, the arms could be rolled up towards their ventral side at their tips.

The second section of the living Ophiuroids—that of the *Ophiurida*—comprises the typical forms of the order, and is characterised by the fact that the arms are always simple and are protected by four rows of integumentary plates (fig. 279). The integument of the disc

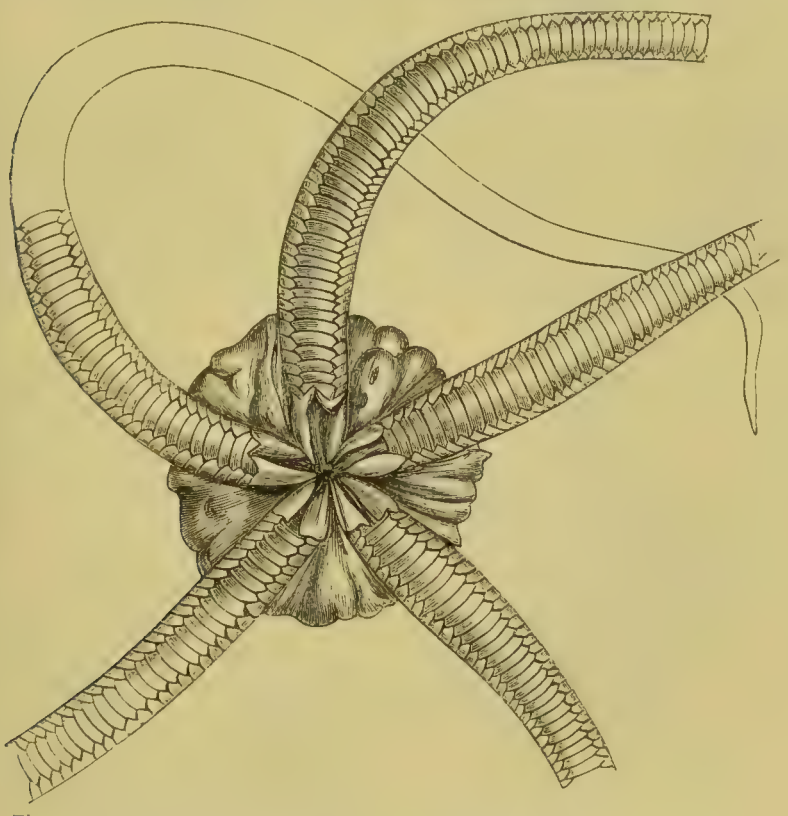


Fig. 279.—Under surface of *Ophioderma* (*Ophioglypha*?) *Gaveyi*, of the natural size. Jurassic (Lias). (After Wright.)

is soft, or is covered with granules or plates of carbonate of lime. The earliest types of this group appear in the Lower Devonian (*Ophiurella primigenia*, Stürtz); and numerous forms are found in the Secondary and Tertiary rocks. A well-known Triassic genus is *Aspidura* (= *Acroura*), the remains of which are widely distributed in the Muschelkalk (fig. 280). The Jurassic Ophiuroids belong principally to the genera *Ophioderma* (fig. 279), *Ophioglypha*, and *Geocoma*, of which the last is peculiar to the Jurassic rocks, while the two former are represented in the Cretaceous and Tertiary rocks,

and survive at the present day. The recent genus *Ophiolepis* is found in the Pleistocene, and possibly occurs in Tertiary deposits also.

Finally, there are various Palæozoic Ophiuroids which cannot be included in either of the preceding sections, and which may be



Fig. 280.—*Aspidura loricata*. Muschelkalk.

provisionally placed in a special division (*Protophiurida*), though their characters are not completely understood. All the forms here in question agree with the typical Ophiurids in having five simple plated arms, but the "madreporite" is placed on the dorsal aspect of the body, and the under surface of the arms exhibits a double,

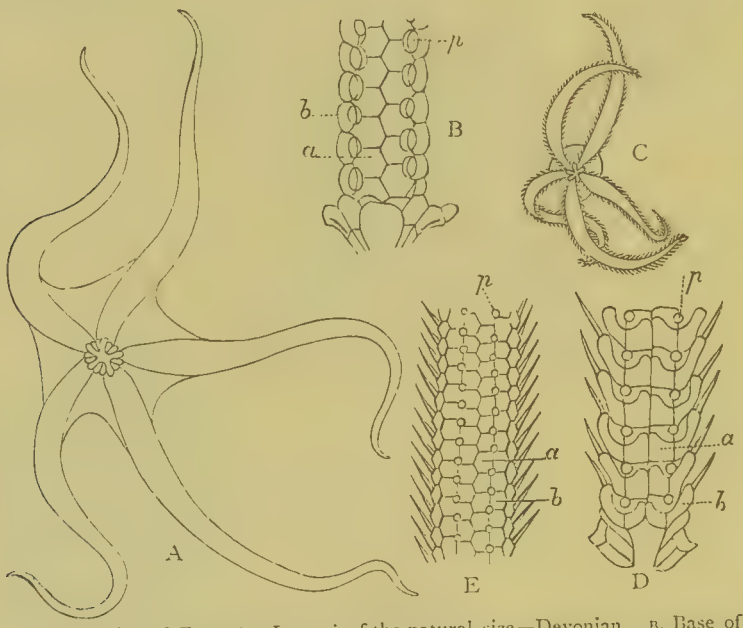


Fig. 281.—A, Outline of *Eugaster Logani*, of the natural size—Devonian. B, Base of an arm of the same viewed from below, enlarged. C, Outline of *Protaster Forbesi*, of the natural size—Silurian. D, Base of an arm of same, viewed from below, enlarged. E, Portion of the arm of *Ptilonaster princeps*, viewed from below, enlarged—Devonian. *a*, Ventral (superambulacral?) plates; *b*, Adambulacral plates; *p*, Pore. (After Hall.)

in place of a single, row of plates (fig. 281, B). Two views may be held as to the nature of the double (or sometimes quadruple) row of plates exhibited on the under side of the arms of the Protophiurids. On one view, these plates are considered as being integument-

ary, and as corresponding with the ventral shields ("superambulacral plates") of the normal Ophiuroids, their special peculiarity on this theory of their nature being their duplication. On the other hand, it may be held that the ventral or superambulacral plates of the ordinary Brittle-Stars are not developed at all in the ancient types in question, and that the double row of plates above alluded to are really the "ambulacral ossicles" or "vertebral discs," which would, on this view, differ from the corresponding structures in the normal Ophiuroids by being separate, instead of being anchylosed in pairs. If this latter view be correct, the Protophiurids may have either had open ambulacral grooves, as in the Asteroids, or the under side of the arms may have been closed by soft skin, as in the Euryalids. Whichever of these two views is the correct one, the plates of the double ventral row of the Protophiurids may either be placed opposite one another, or they may alternate, and they are also so disposed as to give origin to a double series of pores.

Of the genera of Protophiurids, *Protaster* (fig. 282) is found in the Ordovician and Silurian rocks, and is characterised by its round scaly disc, and by the fact that the arms are provided inferiorly with a double row of plates, and carry bunches of lateral spines (fig. 282, B). In the Devonian genus *Eugaster* (fig. 281, A) the general structure is very similar to that of *Protaster*, but the disc is prolonged along the bases of the arms, and the plates of the disc are articulated by their edges, and do not overlap. The under side of the arms (fig. 281, B) exhibits a double row of alternating plates, and lateral spines appear to have been wanting. In the genus *Ptilonaster*, again, the arms exhibit on their under surface *four* rows of plates and a double row of pores. This genus is also Devonian. Lastly, the genus *Tæniaster*, from the Ordovician rocks of Canada, is in many respects like *Protaster*, but the two rows of plates which occupy the under sur-

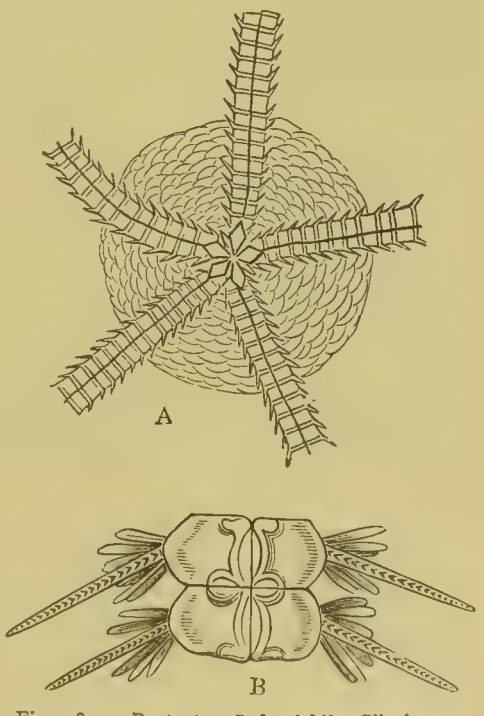


Fig. 282.—*Protaster Sedgwickii.* Silurian. A, Disc and bases of the arms, magnified; B, Portion of an arm, greatly enlarged. (After Salter.)

face of the arms have the peculiarity that each is constricted in the middle, a feature which would rather lead to the belief that these plates are truly of the nature of "ambulacral ossicles."

Class IV. Holothuroidea.

The class of the *Holothuroidea* includes the animals usually known as "Sea-cucumbers," distinguished from the other Echinoderms by their elongated, vermiform, or slug-like form, and their leathery muscular integuments. The mouth and anus are usually terminal in position, and the radial symmetry of the body is not conspicuously shown externally except by the crown of oral tentacles, and, often, by the bands of tube-feet. Palæontologically speaking, the Holothurians are of little importance, since they possess few structures which are capable of preservation in a fossil condition. Unlike the other Echinoderms, the Holothurians exhibit a very limited tendency to a calcification of their tissues. No proper "test," in fact, exists in any Holothurian, but the skin contains numerous isolated, mostly microscopic bodies, of special forms in different types. These calcareous structures (fig. 283) may be globular, wheel-shaped, spicular, anchor-shaped, &c., and

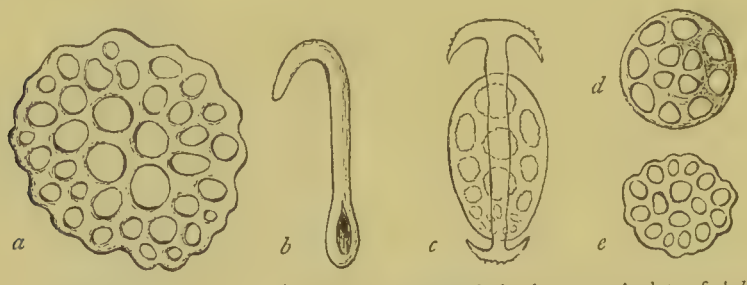


Fig. 283.—Integumentary ossicles of recent and fossil Holothurians. *a*, A plate of *Achistrum Nicholsoni*, enlarged forty-five times, from the Carboniferous rocks of Scotland; *b*, Hooklet of the same, similarly enlarged; *c*, Anchor and anchor-plate of a recent species of *Synapta*, enlarged; *d*, Plate of *Chirodota? Traquairii*, enlarged forty-five times, from the Carboniferous rocks of Scotland; *e*, Plate of the recent *Thyonidium pellucidum*, enlarged. (After R. Etheridge, jun.)

in rare cases (as in *Psolus*) have the form of comparatively large imbricated scales, which constitute a kind of external shell. Whenever the integumentary calcifications are plate-like, they exhibit under the microscope the peculiar netted structure which is characteristic of the Echinodermal test. In addition to the integumentary hard structures, there exists a ring of calcareous pieces surrounding the mouth, and serving for the attachment of five great longitudinal muscles.

Owing to their want of hard structures of any size, the geological history of the Holothurians is necessarily a very imperfect one, being

based only on the occasional recognition of the microscopic plates or spicules of the integumentary skeleton. The oldest remains which can be certainly affirmed to be those of Holothurians are the microscopic plates and spicules described by Mr R. Etheridge, jun., as occurring in the Carboniferous rocks of Scotland. Some of these have the form of rounded, perforated calcareous plates, about $\frac{1}{45}$ inch in diameter, associated with simple calcareous hooks or one-fluked anchors, the shaft of the anchor having a perforation or "eye" at its base (fig. 283, *a* and *b*). These plates and hooklets have been referred to a special genus under the name of *Achistrum;* and they may be compared with the anchors and anchor-plates of the living genus *Synapta* (fig. 283, *c*). Others have the form of circular, generally concavo-convex, wheel-like plates, about $\frac{1}{100}$ inch in diameter, with a group of central pores and a series of marginal perforations (fig. 283, *d*). These resemble the wheel-shaped integumentary plates of such living types as *Thyonidium* (fig. 283, *e*) or *Chirodota*, and they may be provisionally placed in the latter genus.

It is probable that investigations conducted with sufficient care will ultimately show that the minute plates and spicules of Holothurians have been more generally preserved in the fossil condition than has been usually assumed to be the case. In the meanwhile, with the exception of the remains above noted, no undoubted traces of the former existence of Holothurians have been found until the Jurassic rocks are reached. Here, the occurrence of minute wheel-like plates, resembling the "wheels" of the recent *Chirodota* has been recorded. Pocta has described plates of *Psolus* from the Chalk of Bohemia, and Schlumberger has recently found the characteristic armature of *Synapta*, *Chirodota*, and *Thyonidium* in the Middle Eocene of the Paris basin; while *Chirodota* occurs in the Pliocene of Northern Italy, and plates belonging to *Psolus* have been found in Post-tertiary deposits in Bute.

CHAPTER XXV.

DIVISION B. PELMATOZOA.

The three groups of Echinoderms known as the Crinoids, Cystoids, and Blastoids agree with one another in certain common characters, and may be included in a single primary section termed *Pelmatozoa*. In all these forms the body is fixed, either temporarily or permanently, by the dorsal surface, often having a jointed stem or peduncle; and the mouth is placed on the opposite side of the body. In its fully developed condition, the peduncle has the form of a jointed stem, containing a neuro-vascular axis in its interior. The body itself is enclosed in a variously modified series of calcareous plates, which represent the apical disc of the Echinoids, and the upper surface may be provided with jointed appendages (the "arms"). The circular ambulacral vessel has no direct communication with the exterior, or only a limited one, and the radiating ambulacral vessels (when present) are respiratory in function, and are not subservient to locomotion.

Class I. Crinoidea.

The Crinoids or "Sea-lilies" may be defined as Echinoderms in which *the body is fixed, during the whole or a portion of the existence of the animal, to the sea-bottom by means of a jointed, flexible stalk or peduncle, which springs from the centre of the dorsal or aboral surface. The body is cup-shaped or discoidal, and its dorsal surface is protected by a system of calcareous plates. The mouth is situated on the upper surface, generally in the centre. From the margin of the cup-shaped body spring jointed flexible appendages or "arms," which are primitively five in number, and which carry lateral jointed processes or "pinnules." The upper or ventral surfaces of the arms are furnished with grooves corresponding with the "ambulacral grooves" of the Asteroids. The water-vascular system has only a limited communication with the exterior, and is not connected with locomotion. The*

reproductive organs are situated beneath the skin in the grooves on the ventral surface of the arms or pinnules.

As the study of the fossil Crinoids is attended with considerable difficulties, it may be well to give here a brief account of the general anatomy and development of one of the "Feather-stars" (*Comatula*), no other recent type of the group being readily obtainable for purposes of investigation. All the known Crinoids are attached to foreign bodies by a jointed stem or "column" in their young condition; but in the adult state they may either retain this stem of attachment, and thus remain permanently fixed, or they may become



Fig. 284.—Crinoidea. *Antedon* (*Comatula*) *rosacea*, a free Crinoid, viewed from its dorsal or aboral aspect.

detached from the stem and may lead a free existence. In accordance with this, the Crinoids may be divided into the two groups of the "Pedunculate Crinoids" and the "Free Crinoids." In the Pedunculate Crinoids, where the stalk of attachment is permanently retained (fig. 289), the animal may be compared with a Star-fish turned upside down, the column springing from the centre of the "dorsal" (or "abactinal") surface, while the "ventral" (or "ac-

tinal") surface, with the mouth-opening, is turned upwards. In the Free Crinoids, in which the adult is devoid of a peduncle of attachment, the animal has it in its power to move about freely by swimming; while it can at the same time assume the position characteristic of the Stalked Crinoids, since it can fix itself to foreign objects with the mouth turned upwards and the dorsal surface directed downwards.

The "Feather-stars," as exemplified by the common *Antedon* (*Comatula*) *rosacea* of British seas (fig. 284), belong to the group of the "Free Crinoids," being attached by a stalk in their young state only. The adult animal is free, and consists of a pentagonal or cup-shaped body or "calyx," which gives origin on its sides to five jointed processes or "arms." The calyx encloses the visceral mass or disc, the upper or "actinal" surface of which exhibits the apertures of the mouth and anus. The five "arms" bifurcate almost immediately after their origin from the calyx, so as to give rise to ten long slender processes, which are transversely jointed, and

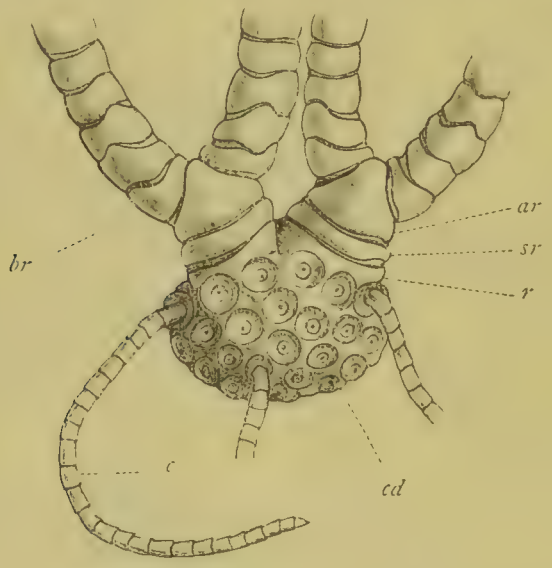


Fig. 285.—Side-view of the calyx of *Antedon* sp., enlarged, the cirri being mostly removed, and the bases of only two rays being shown. *cd*, Centrodorsal plate, with the origins of the dorsal cirri (*c*); *r*, One of the "primary radials"; *sr*, One of the "secondary radials"; *ar*, One of the "axillary radials," carrying the bifurcations of the arm; *br*, First "brachial" plate. (Original.)

are fringed on both sides by delicate filaments or "pinnulæ." The dorsal surface of the body carries a number of delicate jointed flexible processes (figs. 284 and 285, *c*), which are attached to the so-called "centrodorsal" plate, and are known as the "cirri." By means of these the animal can moor itself temporarily to foreign objects, with the mouth turned upwards.

The dorsal or aboral integument is hardened in *Antedon* by the formation within it of a system of calcareous plates, which collectively constitute the "cup" or "calyx," and which in large part correspond with the "apical disc" of the Echinoids. The central piece of the calyx is known as the "centrodorsal" plate (fig. 285, *cd*), and is developed from the topmost joint of the stem in the young Feather-star. It carries the cirri, and has soldered on to it five "radial" plates (fig. 285, *r*), which represent the "ocular plates" of the Echinoids. There are thus *apparently* no representatives of the "genital plates" of the Echinoids. In the great majority of the recent Feather-stars, however, these plates are really present, though they exist only in a metamorphosed condition. They are, in fact, fused together to form a so-called "rosette-plate," which is concealed from view externally, and lies hidden between the centrodorsal and radial plates. This "rosette-plate" consists, therefore, of the amalgamated interradial plates which are known as the "basals" in the stalked Crinoids. Following the first cycle of

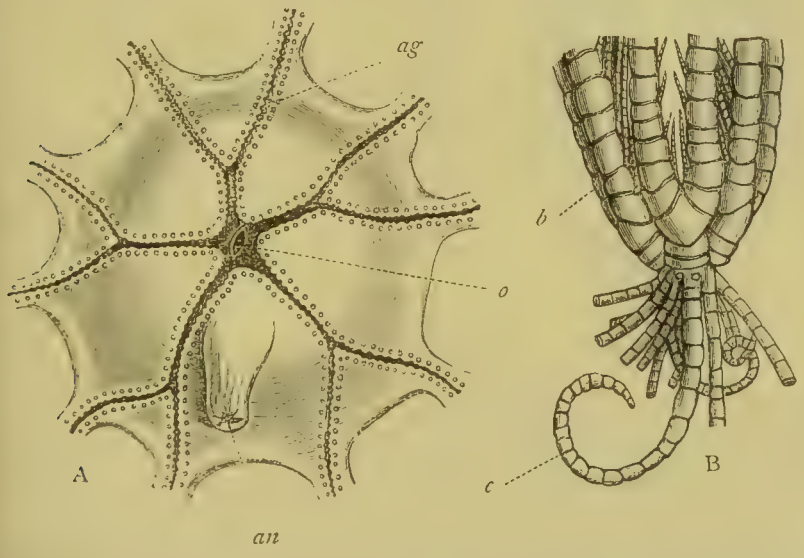


Fig. 286.—A, Ventral or actinal surface of the body of *Comatula* (*Antedon*) *rosacea*, enlarged, showing the central mouth (*o*), the excentric, proboscidiform anus (*an*), and the brachial grooves (*ag*), continued from the bases of the arms across the disc to the mouth. B, Side-view of the lower part of *Antedon lævis*, showing the calyx, the bases of the arms (*b*), and the roots of the dorsal cirri, a single cirrus (*c*) being left complete, enlarged. (After P. Herbert Carpenter.)

"radials" in *Antedon* are two other circles of radial plates (the "second radials" and "axillary radials"), the outermost circle carrying the bases of the jointed arms (fig. 285, *sr* and *ar*).

The upper or ventral surface of the body is covered with an imperfectly calcified, coriaceous skin, and carries the aperture of the mouth. In *Comatula rosacea* the mouth is central (fig. 286, A, *o*),

as it is in all the ordinary Crinoids; but in some Feather-stars (species of *Actinometra*) it may be quite excentric. The anus (*an*) is usually supported on a tubular projection, and is excentric in position. The arms of *Comatula rosacea* exhibit on their ventral surface a deep furrow or groove, the elevated margins of which are cut out into minute crescentic respiratory leaves, at the base of each of which is a group of three tentacles, connected with a cavity in the interior of the respiratory leaf, and communicating by a common trunk with the radiating water-vessel. The floor of the ambulacral furrows is ciliated, and underneath each runs a radiating water-vessel, together with a blood-vascular trunk, and a nerve-band which is in intimate relation with the ambulacral epithelium. In the centre of the arm, between the calcareous skeleton and the water-vessel, are three tubular prolongations of the body-cavity. The middle and largest one of these (fig. 287, *ov*) contains one of the generative glands; while the upper and lower (the "subtentacular" and "cœliac" canals) are much smaller, and permit of a circulation of water derived from the body-cavity. The slender lateral "pinnules" carried by the arms, as regards their internal anatomy, have precisely the structure of the arms themselves.

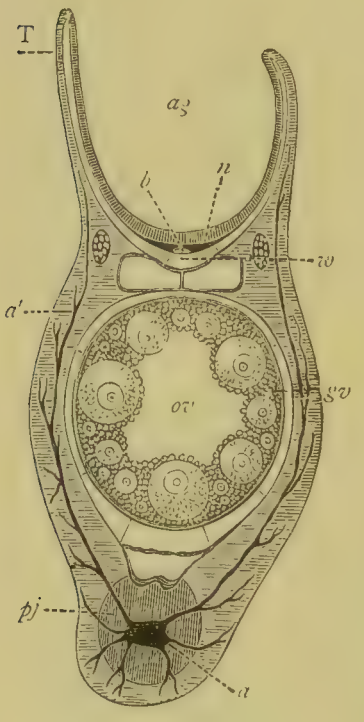


Fig. 287.—Cross-section of a pinnule of the Arctic Feather-star, magnified seventy-five times. (From Ludwig, after P. H. Carpenter.) *pj*, Calcareous skeleton, containing the axial nerve-cord (*a*); *ag*, Ambulacral groove; *n*, Radial nerve; *b*, Radial blood-vessel; *w*, Ambulacral vessel; T, Tentacle; *ov*, Ovary, with the subtentacular canal above, and the cœliac canal below; *gv*, Genital blood-vessel.

The ciliated grooves on the ventral aspect of the arms are continued over the upper surface of the disc to reach the subcentrally or excentrically placed mouth; and the animal feeds upon the minute organisms conveyed to the mouth by the water-currents set up along these grooves. The mouth opens into a spirally coiled alimentary tube, which forms most of the so-called "visceral mass," and is wholly contained within the calyx, no diverticula from it extending into the arms.

The water-vascular system consists of a circumoral ring, and of the radiating water-vessels, which run along the brachial furrows. These give off the tentacles, which are destitute of suckers, and are essentially respiratory in function. The circular ring communi-

cates by numerous water-tubes with the body-cavity, to which the sea-water is freely admitted by minute pores in the body-wall; while some of these pores are said by Perrier to lead directly into the oral water-vascular ring, though this is denied by Hamann.

The vascular system is extraordinarily developed, and its upper portion consists of an oral ring, which gives rise to the radial vessels, and is also connected with a peculiar organ apparently serving as a kidney, as well as with numerous "intervisceral" vessels. There is no aboral vascular ring, but the vessels become connected inferiorly with a singular quinquelocular structure known as the "chambered organ," which is contained within the centro-dorsal plate of the calyx. The chambered organ is enclosed in a peculiar fibrillar sheath, the nature of which will be spoken of immediately, and it sends prolongations into all the arms, along canals contained within the skeleton of the latter, and also into the dorsal cirri.

In the Crinoids generally, the structure of the vascular system is, up to a certain point, much the same as it is in *Comatula*. Occupying the dorsoventral axis of the body is the lobated kidney, enclosed in a sheath of vessels. Dorsally, these resolve themselves into a central group (of one or more), and five peripheral vessels, the latter expanding in the lower part of the calyx into the five chambers of the "chambered organ." In the Pedunculate Crinoids the chambers narrow again, and the group of vessels is continued down the central canal of the column. In *Pentacrinus*, which has cirri at regular intervals, the five peripheral vessels expand in each cirrus-bearing joint into five dilatations, which thus give rise to a miniature "chambered organ," each chamber of which gives off a single vessel to a cirrus.

The nervous system of the Feather-stars is also extraordinarily developed as compared with that of the other Echinoderms. As has been previously seen, there is found under the floor of each of the brachial grooves a fibrous nerve-band (fig. 287, *n*), which corresponds morphologically with one of the radiating nerve-fibres of a Star-fish. In addition to these ambulacral nerves, the "chambered organ," above spoken of in connection with the vascular system, is enclosed in a peculiar fibrillated sheath, which has been shown by Dr W. B. Carpenter to be of a nervous nature. It gives off a series of radial prolongations or "axial cords" (fig. 287, *a*), which occupy median canals within the skeleton of the arms and pinnules, and send numerous branches to the muscles and the integument (fig. 287, *a'*). In the stalked Crinoids the fibrillar nerve-sheath is likewise prolonged, along with the blood-vessels, into the central canal of the column or peduncle. No representative of this peculiar system of nerves is known in the unstalked Echinoderms (*Echinozoa*).

Though free in its adult condition, the Rosy Feather-star passes through a stage of its development in which it is attached by a delicate jointed stalk to some foreign object (fig. 288). When first discovered in this condition, it was supposed to be a distinct type of the Crinoids, and was described under the name of *Pentacrinus Europæus*. The *Comatula*, therefore, represents temporarily, in this stage of its development, the permanent condition of the Pedunculate Crinoids.

As regards the development of *Comatula*, the larva is at first cylindrical, with four transverse bands of cilia, a hinder tuft of cilia, and an alimentary canal furnished with a lateral aperture, its general aspect closely resembling that of the embryos of certain Annelides. The skeleton of the calyx is developed anteriorly, that of the column posteriorly, the former being the first to appear. In its early condition (fig. 288) the calycine skeleton consists of a row of five "basal" plates (*b*), together with three or five small "underbasals," which rest below upon the so-called "centrodorsal plate" (*cd*), and fuse with it at an early period. The basals are succeeded above by a cycle of five "oral" plates (*o*), in the centre of which the permanent mouth is finally developed. Five "radial" plates (*r*) are next developed as a cycle between the oral and basal plates: and to the radials are rapidly added the plates of the arms proper (the "brachials). Inferiorly, the centrodorsal plate rests upon a short jointed column (fig. 288, *c*), at the bottom of which is an expanded "dorsocentral" plate (*d*), forming a disc of attachment; and the larva now passes into what is known as its "Pentacrinus stage." In the further progress of growth the arms increase in length, and the oral plates diminish in size and ultimately disappear. At the same time the centrodorsal plate increases in size, so as to enclose the basal plates, which in turn become fused with one another, and remain only as the so-called "rosette" on the upper surface of the centrodorsal. The latter also develops jointed cirri from its outer suface, and finally becomes detached from the next joint of the column below, when the animal enters upon its free stage of life.

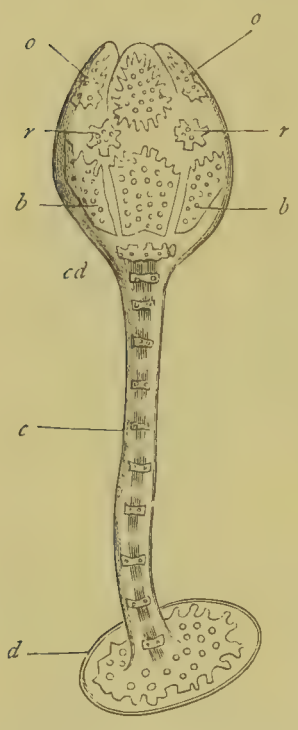


Fig. 288.—Larva of *Comatula* (*Antedon*) *rosacea*, enlarged (after Sir Wyville Thomson). *o o*, Oral plates; *r r*, Radial plates; *b b*, Basal plates; *cd*, Centrodorsal plate; *c*, Column; *d*, Disc of attachment (dorsocentral plate).

As regards the essential features in their anatomy, the "Stalked" Crinoids do not differ materially from the "Free" forms of the group. More particularly, there is a substantial identity in structure in the two sections of the order as regards the form and arrangement of the alimentary canal, the ambulacral and vascular systems, and the nervous and reproductive organs. As the majority of the fossil Crin-

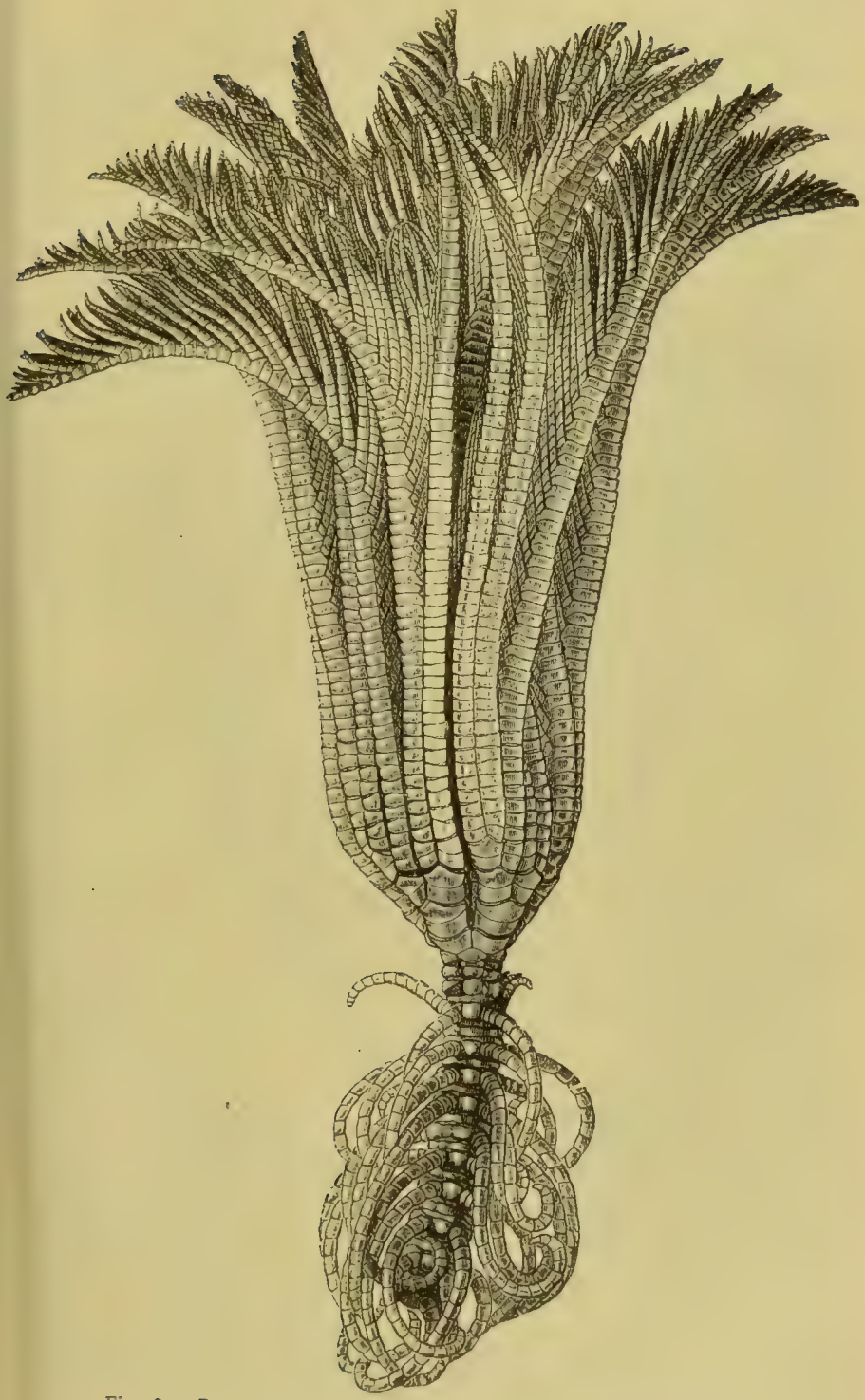


Fig. 289.—*Pentacrinus Macleayanus*, a living stalked Crinoid, slightly enlarged.

oids, however, belong to the Pedunculate division of the group, it is necessary to study the skeleton of these in greater detail.

A pedunculate Crinoid, such as *Pentacrinus* (fig. 289), consists of a cup-shaped body or "calyx," which encloses the principal viscera, and is furnished with a crown of pinnate "arms," and which is attached to some foreign object by means of a stalk or "column," composed of a number of calcareous pieces or "articulations." In some cases (as in *Apiocrinus*) the base of the "column" is considerably expanded. In other cases the column is simply "rooted by a whorl of terminal cirri in soft mud" (Wyville Thomson). The column may be extremely short, or even wanting in the adult, or may reach the extraordinary length of sixty or seventy feet. The whole column is composed of a series of ring-like or pentagonal joints, which are generally movably articulated with one another, and are furnished with special muscles, the joint-surfaces often having a very elaborate structure, and the entire stem possessing in the living state a larger or smaller amount of flexibility. Very often more or fewer of the column-joints carry lateral jointed processes or "cirri" (fig. 289). Each joint of the stem, further, is perforated centrally by a canal, which lodges an extension from the "chambered organ" and its fibrillar nerve-sheath.

As regards its shape, the "column" of the Stalked Crinoids is very commonly round, but it is sometimes oval or elliptical (as in *Platycrinus*, fig. 300), and it is not infrequently pentagonal (as in *Extracrinus*, fig. 290). The separate joints or "articulations" of the column are usually so connected with one another that whilst the amount of movement between any two pieces must be very limited, the entire stem is more or less flexible. The articular surfaces or facets by which contiguous joints are connected, are differently marked in different cases. In many forms, the articulating facets are marked by more or less numerous radiating striæ, which run from the central canal of the joint to its margin. In other cases, as in *Pentacrinus* and *Extracrinus* (fig. 290), the articular faces are united by crenated ridges arranged in a pentapetalous figure. Though usually articulated movably, the stem-joints are occasionally united here and there by the peculiar mode of union known as "syzygy." By this is understood the immovable union of two originally separate joints by close ligamentous connection and subsequent more or less complete fusion, the primitive line of division usually remaining visible as a line of suture.

The uppermost joint of the column is often larger than, and differently shaped from, the inferior joints, and may, as in *Apiocrinus*, enter largely into the formation of the calyx. In many cases, as in *Pentacrinus* and *Extracrinus* (figs. 289 and 290), the column is furnished with more or less numerous auxiliary arms or "side-arms," which represent the "cirri" of the Comatulids. The column generally increases in height by the addition of new joints at its summit, and also by the intercalation of others between those previously formed in the upper, and therefore the youngest, part of the stem; and the whole series is traversed centrally by a variously shaped tube—the misnamed "alimentary canal" of old writers.

—which, as previously noted, lodges the neuro-vascular axis of the stem. The neuro-vascular tube of the stem sends off diverticula into the cirri and root-like processes of attachment, when these structures are present. It is very commonly round, but it may be pentapetalous. In some cases, there are four or five canals running parallel with and around a central tube, but in this case the function of the outer circle of tubes is uncertain.



Fig. 290.—*Extracrinus briaroides*, from the Lias, showing the crown of arms, and the column with its side-arms. The small figures show the stem-joints of *Extracrinus subangularis*.

The column carries at its summit the cup-shaped, pyriform, or bursiform body of the animal, or "calyx" (fig. 291). As the column is produced from the aboral pole of the animal, it is the

dorsal side of the calyx which is turned downwards, while the ventral or oral side is turned upwards. The dorsal or inferior side of the calyx is entirely enclosed in a series of polygonal calcareous plates, which are more or less closely joined together. In some cases the plates are united by firm sutures; while in others the plates are more or less movably articulated; and in still other cases certain of the plates may be connected by the peculiar mode of immovable union, which has been already described under the name of "syzygy." In rare cases, as in the Devonian genus *Hystricrinus*, the calycine plates are furnished externally with movably articulated spines, resembling the prickles of the Echinoids.

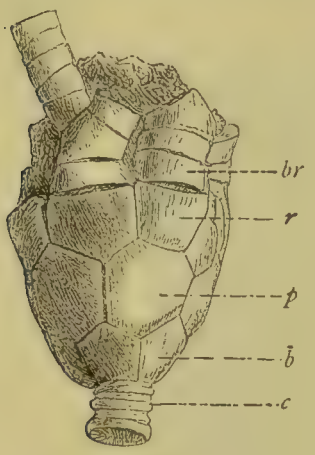


Fig. 291.—Side-view of the calyx of *Poteriocrinus multiplex*, from the Carboniferous Limestone of Russia, of the natural size, showing the top-joints of the column (*c*) and the bases of the arms. *b*, The cycle of "underbasals"; *p*, The "basals"; *r*, The "primary radials"; *br*, The "second radials" (or first "brachials" of some authors). (After Zittel.)

The following is the general arrangement of the calycine plates in the Stalked Crinoids (figs. 291 and 292). Resting directly upon the summit of the highest joint of the column is the cup-shaped basal portion of the calyx, which is known as the "basis," and which may consist of a single or double row of plates. In those Crinoids in which the basis is composed of a single row of plates only—hence termed "monocyclic" Crinoids—its component plates rest directly upon the top-joint of the column, and are known as the "basals." The "basals" are interradial in position, and are homologous with the "genital plates" in the apical disc of the Echinoids. The basals are usually five in number, but may be reduced to four, three, or two; and they may be invisible externally owing to their concealment by the radials (as in most *Comatulæ*). In the so-called "dicyclic" Crinoids, on the other hand, the true "basals" retain their constant interradial position, but are separated from the top-joint of the column by an intercalated row of plates termed the "underbasals" (figs. 291 and 292, *b*), the basis thus consisting of two successive cycles of plates.[1] The underbasals are radial in position, and have no representative in the calyx of the "monocyclic" Crinoids. It is not clear that they possess any homologues in the apical disc of the Sea-urchins, as do the basals and radials of the Crinoidal calyx. They were formerly compared

[1] In the nomenclature of some writers, the plates of the dicyclic calyx are known respectively as the "basals" and "parabasals"; but the nomenclature of Dr P. Herbert Carpenter, employed above, undoubtedly expresses the true homologies of the monocyclic and dicyclic forms.

collectively to the "suranal" or dorsocentral plate of the *Saleniadæ*, which is represented in the larvæ of other Urchins; but it is now generally admitted that the homologue of this plate in the Crinoids is the plate supporting the discoidal base of the larval stem (fig. 288, *d*). Succeeding the basals, and alternating with them, are one or more cycles of plates, which are directly superimposed upon one another in longitudinal rows, and which form the foundations of the arms. The lowest of these, up to the first bifurcation, are known as the "radials" (figs. 291, 292, *r*), and are termed "primary," "secondary," or "tertiary" radials, according to their distance from the basals. The last

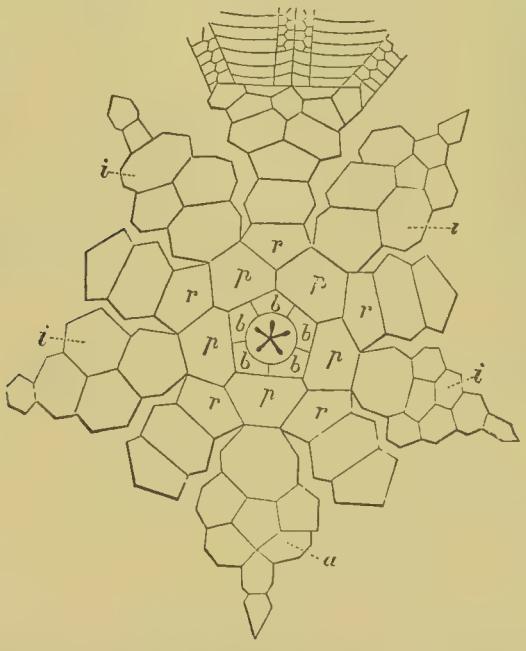


Fig. 292.—Diagram of the dissected calyx of *Rhodocrinus*, a "dicyclic" Crinoid, viewed from below (after Schultze). *b*, Underbasals; *p*, Basals; *r*, First radials; *i*, Interradials; *a*, Anal plates.

radial plates, or those furthest from the column, are the "axillary" radials, and give origin to the lowest plates of the arms ("brachial" plates); or, if the cycle of the primary radials alone is developed, the first brachials rest upon these. The "radial" plates are arranged in a series of five vertical columns, which are, as the name implies, radial in position; and the primary radials are homologous with the "ocular plates" in the apical disc of the Echinoids.[1]

[1] From the strict morphological point of view, these primary radials are the only plates to which the name "radials" is applicable, all those which follow them being really arm-joints ("brachials"). It is, however, convenient for descriptive purposes to give the name of "radials" to all those plates which are

Between the five columns of radial plates, corresponding with the five arms, there may be intercalated certain other smaller plates, which, from their position, are spoken of as "interradials" (fig. 292, *i*). When "interradials" are developed, one of the interradial spaces, corresponding with the anus, is usually wider than the others, and is furnished with an additional series of calcareous pieces, which are termed "anal plates" (fig. 292, *a*).

As above mentioned, the first brachial plates rest directly upon the highest row of radials; and the "arms," therefore, spring from the margins of the calyx, where the dorsal and ventral surfaces join. The arms are formed of a single or double longitudinal row of "brachial ossicles," the plates in the latter case alternating with one another. The brachial plates are in many cases traversed by a single or double canal, which transmits the axial nerve-cord (fig. 287). In most cases, the brachial ossicles are movably articulated with one another, having their opposed surfaces separated by interarticular substance, and being provided with muscular fasciculi. In other cases, however, the arm-plates are fixed in immovable junction by "syzygy," and may coalesce with one another. The arms are primarily five in number, and they may remain simple. Most commonly, however, the arms are more or less branched, and they generally carry on their sides short, jointed filaments or "pinnules," the structure of which repeats that of the arms on a smaller scale (fig. 293). Pinnulæ may be wanting (as in *Cyathocrinus*), and it is not always easy to distinguish between "pinnules," properly so called, and "armlets" (*i.e.*, short divisions of the arms themselves); since the real distinction between these structures depends upon their contained soft parts, and is therefore unavailable as regards fossil forms. The proper "arms," namely, lodge the sterile genital cord, while it is within the pinnules that the fertile portions of the genital glands are contained. Owing to the position of the reproductive glands beneath the soft skin of the pinnules, it follows that there exists no generative opening, or "ovarian aperture," in the walls of the calyx, such as is present in the Cystideans.



Fig. 293.—Portion of an arm of *Platycrinus*, showing the lateral pinnulæ.

The ventral surfaces of the arms and pinnules, as in *Comatula*, are furnished with furrows—the "ambulacral grooves" or "food-

situated in the direction of the rays, as far as the first axillary joint; and when the arms are numerous, some authors speak of secondary and tertiary radials according to the number of axillaries between the basals and the free arms.

grooves"—which ultimately coalesce to form five primary grooves, which are continued across the ventral surface of the disc to the mouth (fig. 286, A). These ambulacral grooves, in living forms, are ciliated, and along them currents of water are kept up, by which organic particles are conveyed to the mouth. In a number of types, including numerous extinct and a few living forms, the ambulacral furrows are covered in superficially by two, or, more rarely, by four rows of alternating calcareous plates of small size.

The upper or ventral surface of the visceral mass or disc is in all living Crinoids, whether stalked or free, covered with a leathery skin containing calcareous granules or plates, which are sometimes scattered, but sometimes very closely placed; and it exhibits the five principal ambulacral grooves as generally open furrows passing from the bases of the arms to the mouth (fig. 286, A). The mouth itself is central in position, or, rarely, excentric (*Actinometra*), and may be surrounded with five triangular "oral plates," which alternate with the ambulacral grooves. In most *Comatulæ*, the oral plates are present only in the early stages of development (fig. 288), and disappear in the adult; though they are relatively large and well developed in *Thaumatocrinus*. Almost all the Secondary and Tertiary Crinoids resembled the ordinary living forms in the possession of a plated ventral perisome and open ambulacral grooves; and hence such forms have been grouped together by Dr P. H. Carpenter under the name of "Neocrinoids." In all recent Crinoids, further, the upper surface of the body exhibits the aperture of the anus, which is generally excentric, though central in position in some *Actinometræ*, and which is usually placed at the summit of a proboscidiform eminence (fig. 286, A).

On the other hand, in the so-called "Palæocrinoids," embracing under this name all the Crinoids of the Palæozoic rocks, the upper surface of the calyx rarely exhibits open ambulacral grooves, nor is the mouth-opening generally exposed to view. On the contrary, the oral aperture and food-grooves are more or less completely concealed beneath a superficial plated covering, the structure of which varies in different groups. In very many cases, as in the *Actinocrinidæ*, *Platycrinidæ*, *Rhodocrinidæ*, &c., the ventral surface of the calyx is roofed over by a flat or vaulted canopy of calcareous plates, which are firmly united with one another, and completely conceal the subjacent mouth-opening and ambulacral grooves. Five plates which meet in the centre of this vault correspond to the "oral plates" of the Neocrinoids. One of these is larger than the rest, and immediately behind it the vault is perforated by a single, excentric, or, rarely, central aperture, which is often prolonged into a tubular "proboscis," and which is to be regarded as the anus. In all such cases, the ambulacral grooves are continued beneath the above-mentioned

canopy, from the bases of the arms, across the ventral aspect of the calyx, as so many tunnels. During life these lodged both the food-grooves and the water-vessels beneath them, and there is evidence that the latter opened into a circular vessel surrounding the mouth and representing the circular ambulacral vessel of the Echinoderms generally. Hence in specimens of such forms, where the arms have been detached (figs. 294-296), the upper side of the calyx is seen

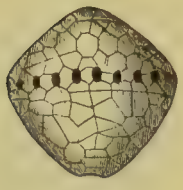


Fig. 294.—Calyx of *Actinocrinus rotundus.*

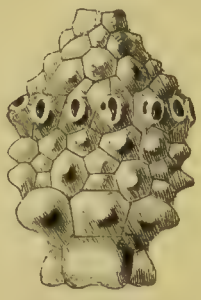


Fig. 295.—Calyx of *Actinocrinus Koninckı.*



Fig. 296.—Calyx of *A. Verneuillanus.* The arms are wanting, and the apertures of the food-grooves at their bases are seen.

to be covered with a plated dome, and the points of insertion of the arms are marked by the openings of the food-grooves on their way inwards to the concealed mouth.

In the great family of the *Cyathocrinidæ*, among the Palæocrinoids, the mouth and convergent food-grooves are concealed from view by a vault which is chiefly composed of the "oral" plates in the centre, together with the united covering-plates of the ambulacra (fig. 297, A). These are all of a much less massive character than in the forms above mentioned, and are readily destroyed. When these tegminal plates have not been preserved—as is very commonly the case—then the upper surface of the calyx (fig. 297, B) exhibits a large central peristomial opening, to which the five ambulacral grooves converge, together with an excentrically placed and often proboscidiform anus. In this family, the peristome is surrounded by five large calyx-interradials, of which one (the "anal plate," fig. 297, *a*) is excavated on one side, and corresponds with the anus. The

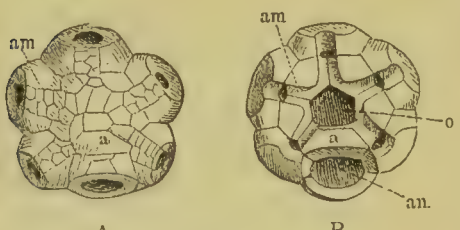


Fig. 297.—Upper surface of the calyx of *Cyathocrinus malvaceus*, showing the superficial plating of the disc preserved (A) and the same removed (B). *am*, Ambulacral grooves, in the one figure roofed in by a double row of minute ossicles, and in the other figure open; *a*, "Anal plate"; *o*, Peristome; *an*, Anus. (After Zittel.)

general structure of the "tegmen calycis" in the great Palæozoic family of the *Poteriocrinidæ* is the same as in the *Cyathocrinidæ*, but both the interradials and the "oral plates" are often inconspicuous, or imperfectly developed. In these forms, also, the excentric anus is prolonged into a proboscidiform tube, which is often of great size (fig. 298).

As regards the *classification* of the Crinoids, the first well-grounded systematic arrangement was that proposed by Johannes Müller, who divided the order into the three sections of the *Tessellata*, the *Articulata*, and the *Costata*. The first of these sections included the Palæozoic Crinoids, and its name was based on the fact that in these the plates of the calyx are united by sutures which do not admit of movement. The section of the *Articulata*, again, included the living, Tertiary, and Secondary Crinoids (*Marsupites* alone excepted), in which the calycine plates are movably articulated; while the section *Costata* comprised only the aberrant Jurassic genus *Saccocoma*. Zittel, in his admirable 'Handbuch der Palæontologie,' has followed Müller's classification, with various emendations and modifications. Müller's classification, though a great advance upon that proposed by his predecessors, cannot be considered, even as modified by Zittel, to be a strictly natural one, since forms which agree in all the other main points of their organisation may differ as regards the mode in which the calycine plates are joined together. Thus the family of the *Ichthyocrinidæ*, though closely resembling the other Palæozoic Crinoids in its essential organisation, is characterised by the possession of movably articulated radial plates, and thus should properly fall under the section of the *Articulata*. The classification which will be here followed is that adopted by Dr P. Herbert Carpenter and by Mr Charles Wachsmuth, in which the *Crinoidea* are divided into the two primary sections of the *Palæocrinoidea* and *Neocrinoidea*. In the division of the *Palæocrinoidea* are comprised all the known Palæozoic Crinoids, and the distinguishing characters of the division are,

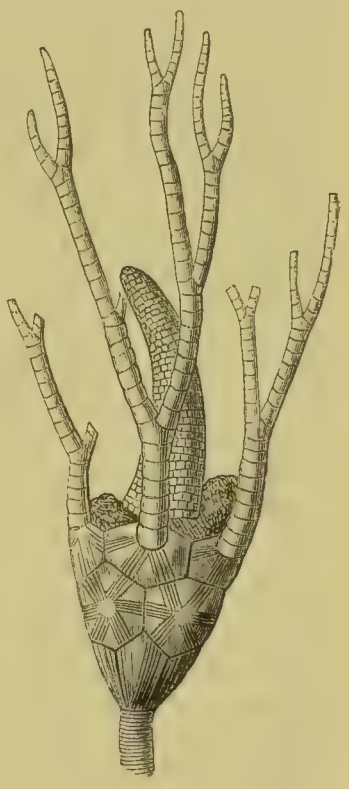


Fig. 298.—Calyx and part of the arms of *Poteriocrinus radiatus*, showing the proboscidiform anal tube. Carboniferous. (After De Koninck and Le Hon.)

roughly speaking, that the calyx is disproportionately large and massively constructed as compared with the arms, interradials being usually present and often united with the radials in such a way as to form a portion of the calyx; while the anal interradius is specially developed, thus rendering the cup unsymmetrical. Moreover, the mouth and food-grooves are generally concealed from view by the development of a more or less definite "vault" above the proper ventral surface of the calyx. On the other hand, the *Neocrinoidea* are all Secondary, Tertiary, or Recent, and are roughly distinguished from the Palæocrinoids by the comparatively small size of the usually symmetrical calyx and the proportionately large development of the arms. The interradials, if present, are rarely incorporated into the calyx, and with one exception (*Thaumatocrinus*) an "anal" interradius cannot be recognised. The higher radial plates are more or less movably articulated, and do not enter into the composition of the calyx. Lastly, the ventral surface of the visceral mass is not covered by a plated dome, but the mouth and ambulacral grooves are exposed to view. Speaking generally, the division *Palæocrinoidea* may be regarded as corresponding with Müller's division of the *Tessellata*, while the section *Neocrinoidea* corresponds with the *Articulata* and *Costata* of the same author.

As regards the *distribution* of the Crinoids *in space*, the order is represented by comparatively few forms in recent seas, and these have mostly a very local range. All the existing forms belong to the division of the Neocrinoids, and the majority of them are referable to the free-living family of the *Comatulidæ*, of which there are not far from two hundred known forms, belonging to six genera (*Antedon*, *Actinometra*, *Atelecrinus*, *Eudiocrinus*, *Promachocrinus*, and *Thaumatocrinus*). On the other hand, there are only about forty known living types of the "Pedunculate" Crinoids, belonging to some half-a-dozen genera (*Pentacrinus*, *Rhizocrinus*, *Bathycrinus*, *Hyocrinus*, *Metacrinus*, and *Holopus*). The *Comatulidæ* have a very wide range in space, being found in almost all seas, but they are essentially inhabitants of shallow water. Many of the living stalked Crinoids, on the other hand, such as *Bathycrinus* and *Hyocrinus*, are only found at great depths in the sea. They do not range, however, below 2500 fathoms, while one species of *Antedon* occurs at a depth of 2900 fathoms.

As regards their *distribution in time*, the entire group of the Palæocrinoids is restricted to the Palæozoic period, and may be said to have attained its maximum development in rocks as ancient as the Silurian. Throughout all Palæozoic time the Crinoids are the predominant types of the Echinoderms, and many of the Ordovician, Silurian, Devonian, and Carboniferous limestones are so extensively

composed of the fragmentary remains of these organisms that they may be properly spoken of as "crinoidal limestones" and "encrinital marbles." The Permian formation (Dyas) is singularly poor in remains of Crinoids, and the commencement of Mesozoic time appears to have been signalised by the complete disappearance of the Palæocrinoids, and the coming in of the Neocrinoids. The first forms of this latter group make their appearance in the Trias (*Encrinus*, &c.), and numerous types are known in the Jurassic and Cretaceous rocks, but the Crinoids no longer play a part of such conspicuous importance as we have seen to have been the case in the Palæozoic period. The earliest forms of the great modern family of the *Comatulidæ* appear in the lower part of the Jurassic system (Middle Lias). The Tertiary formations are by no means rich in Crinoids, and the comparatively limited recent Crinoidal fauna must be regarded as a survival from the earlier part of the Mesozoic period, most of the living types being closely connected with forms which existed at the time when the Triassic and Jurassic deposits were laid down.

In the following synopsis of the families of the *Crinoidea*, the characters and distribution in time of the leading groups will be briefly touched upon, but the less important families can only be defined in the shortest manner possible. The arrangement followed is, in the main, that adopted by Wachsmuth and Springer as regards the Palæocrinoids and by Dr P. Herbert Carpenter as regards the Neocrinoids.

Division A. Palæocrinoidea.

The division of the *Palæocrinoidea* corresponds with Müller's division of the *Tessellata*, as redefined by Zittel, *minus* the two Mesozoic genera *Marsupites* and *Uintacrinus*. The calyx in the Palæocrinoids is comparatively large, with massive plates, and is usually unsymmetrical, the arms being proportionately small. Interradials are usually present, while the anal interradius is specially developed and is readily recognisable. A certain number of the plates above the primary radials are, as a rule, "closely united to one another and to the interradials, so as to form the walls of a relatively large and substantial calyx" (P. H. Carpenter). The ventral surface is covered by a more or less extensive vault, the centre of which is generally occupied by the united oral plates, concealing the mouth and the origins of the ambulacra (fig. 297).

Family 1. *Actinocrinidæ*.—The calyx in this family is always "monocyclic," there being three to five basals, but no "underbasals" (fig. 299). The plates of the cup are firmly united by suture, and the radials take part in the formation of the calyx. Interradial plates are developed, and the lowest "anal" interradial rests directly upon the basals. The arms may be uniserial or biserial

—*i.e.*, they may consist of a single or double row of brachials—but they are most commonly the latter. The ventral surface of the calyx is covered with a vault of heavy plates which are closely connected together. The geological range of the family is from the Ordovician to the Carboniferous inclusive.

The type-genus of this family is *Actinocrinus* itself, in which the calyx, though very variable in shape (figs. 294-296), always possesses three basals, which form a hexagon, and are united superiorly with the five primary radials and the lowest of the anal interradials. There are three cycles of radials, and the highest radials carry each a double series of brachial plates, which support the variously divided arms. There are three or more anal plates, of which the lowest (fig. 299, *a*) always rests upon the basals directly. There is a variable number of interradials, and the column is round. The upper surface of the cup is vaulted over with calcareous plates, and the brachial grooves are continued beneath the vault thus formed, as so many tunnels, to the central and concealed mouth. The anus may or may not be extended into a proboscis, and it is sometimes very excentric, sometimes subcentral. It has been shown that in some of the *Actinocrinidæ* (as in forms belonging to other families) there exists in the interior of the calyx a singular convoluted calcareous plate, of a reticulated texture, shaped somewhat like an ordinary Bubble-shell (*Bulla*), occupying the vertical axis of the body, and often of large size. This has been compared with the calcareous structures present in the "sand-canal" of various Echinoderms; but it is probably rather an extreme development of the discoidal calcareous plates which have been described as strengthening the double wall of the spirally-twisted alimentary canal in the living *Comatulæ*. The genus *Actinocrinus* appears to commence in the Silurian, and is also represented in the Devonian; but it attains its maximum in the Carboniferous, and is wholly unknown in later deposits. *Agaricocrinus* and *Batocrinus* are Carboniferous forms very closely allied to *Actinocrinus*. The Silurian genera *Periechocrinus* and *Megistocrinus* are close allies of *Actinocrinus*, and the Carboniferous *Amphoracrinus* and *Dorycrinus* only differ from it in comparatively trifling particulars.

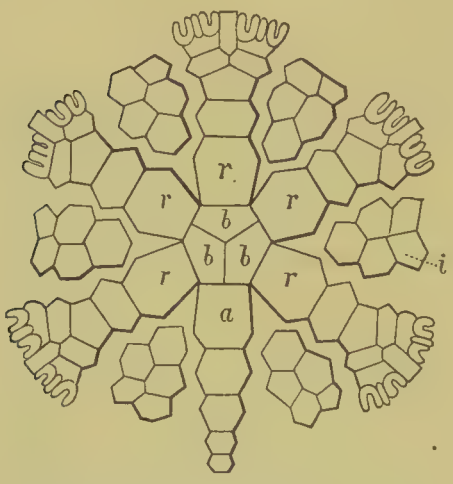


Fig. 299.—Diagram of the dissected calyx of *Actinocrinus* (after Schultze). *b*, Basals; *r*, Radials; *i*, Interradials; *a*, The lowest of the anal plates.

In the Silurian and Devonian genus *Melocrinus*, there are four or three basals, the lowest anal plate is separated from the basals by the primary radials, and the arms are in the form of five free rays giving off lateral armlets. *Melocrinus* is often regarded as the type of the separate family of the *Melocrinidæ*, to which Wachsmuth and Springer also refer the genus *Glyptocrinus*, which will be briefly noticed later.

Among the other genera of the *Actinocrinidæ* may be mentioned *Stelidiocrinus*, *Briarocrinus*, and *Carpocrinus*, which have been regarded as the types of as many families, and all of which are found in the Silurian rocks.

Family 2. *Barrandeocrinidæ*.—This family has been founded by Angelin for the reception of the single genus *Barrandeocrinus*, which occurs in the Silurian rocks of Gotland. In this genus the arms are arranged in pairs, and are reflexed in such a way that their dorsal surfaces rest upon the outer surface of the calyx, while they are at the same time confluent laterally.

Family 3. *Platycrinidæ*. — This family is characterised by the possession of a "monocyclic" calyx, with three, or sometimes two,

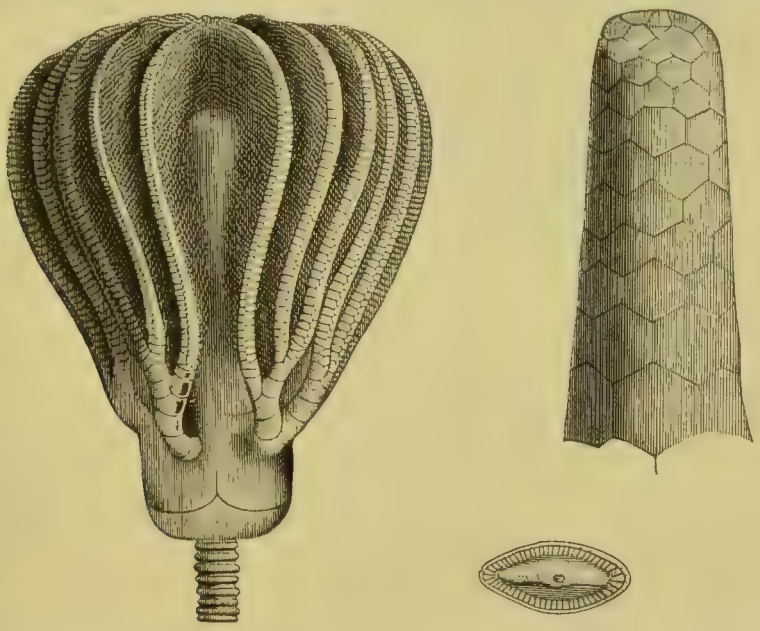


Fig. 300.—*Platycrinus tricontadactylus*. Carboniferous. The left-hand figure shows the calyx, arms, and upper part of the stem, and the figure next this shows the surface of one of the joints of the column. The right-hand figure shows the proboscis.

basals and five radials. There are from three to five plates in each interradial space; but the anal interradials do not come in contact with the basals, except in some forms (*Hexacrinus*). The arms are at least ten in number (fig. 300), and may be uniserial or biserial. The column is round or elliptical, and the neurovascular axial canal is of small size. The geological range of the family is from the Silurian to the Carboniferous inclusive, but the maximum development is attained in the Carboniferous Limestone.

The type-genus of the *Platycrinidæ* is *Platycrinus* itself, in which the cup is composed of three basals and a single cycle of radials, amongst

which the anal interradial is not intercalated. The succeeding radials are embraced in the free arms, and do not form part of the calyx. The arms are numerous and bifurcated, and all the divisions carry pinnules. There are three or five interradials in each of the interradial spaces, and there may be one large, or three small anal plates. The column is rounded near the calyx, but its lower joints are oval and compressed. There is, typically, a large anal proboscis. In connection with the proboscis of *Platycrinus*, we may just notice the well-known fact that in many specimens (as is the case with other Crinoids possessing a similar elongated anal tube) there is found in close apposition with the proboscis, and often placed upon its actual summit, the shell of a fossil Univalve (apparently almost always, or always, a species of *Platyceras*). It was originally supposed that the Crinoid had been fossilised in the act of eating the Mollusc—the anal tube being regarded as the mouth—but all the living Crinoids feed upon microscopic animalcules, and this supposition is therefore, *prima facie*, an improbable one. It has also been shown by Meek and Worthen that the *Platyceras* must have lived for a long time attached to the proboscis of the Crinoid, since the lip of its shell has closely adapted its form to that of the surface to which it is attached. We may therefore safely accept the conclusion reached by these observers, that the *Platyceras* was in the habit of attaching itself parasitically to the side or summit of the proboscis of *Platycrinus* and other Crinoids, thus obtaining a share of the minute animalcules upon which its host lived.

The genus *Platycrinus*, as defined by Wachsmuth and Springer, is almost entirely confined to the Carboniferous period, being represented by many species in the Carboniferous Limestone. One or two small forms, however, occur in the Devonian. The genus *Hexacrinus* is closely allied to *Platycrinus*, but it possesses a large anal plate, which rests directly upon the basals (as in *Actinocrinus*). The genus is strictly Devonian, and the species are mostly European.

By Wachsmuth and Springer the genus *Hexacrinus* is regarded, probably correctly, as the type of the distinct family of the *Hexacrinidæ*, to which they also refer *Hystricrinus* and *Dichocrinus*. Of the remaining genera of the *Platycrinidæ*, the only one which needs special mention is the somewhat aberrant Ordovician and Devonian genus *Coccocrinus*. In this genus, the vault is entirely formed by five large oral plates, which rest upon the interradials and conceal the mouth.

Family 4. *Rhodocrinidæ*.—The forms included in this family have a dicyclic calyx (fig. 292), but the underbasals may be very small, and are sometimes completely concealed from external view (*Glyptocrinus*). The underbasals are usually five in number, sometimes three: and there are five basals. Interradials are well developed, but the anal interradius is "scarcely distinct" (Wachsmuth and Springer). A very characteristic feature, however, is that the first radials are separated by interradials which rest upon the basals. The arms may be uniserial or biserial. The species of this family range from the Ordovician to the Carboniferous inclusive.

The type-genus of this family is *Rhodocrinus* itself, which ranges from the Silurian to the Carboniferous. The underbasals in this genus (fig. 292) are five in number, and are well developed. The five lowest interradials

rest upon the basals, and form with the first radials a ring of ten plates; while the arms, varying in number from ten to twenty, are bifurcated two or three times during their course. Allied to *Rhodocrinus* is the genus *Ollacrinus* (*Gilbertsocrinus*) of the Carboniferous Limestone.

The genus *Glyptocrinus* has been commonly referred to the *Rhodocrinidæ*, but it is now placed by Wachsmuth and Springer in the *Melocrinidæ*, while other authorities regard it as the type of a separate family (*Glyptocrinidæ*). In this genus, the turbinate calyx possesses underbasals, but these are of small size, and may be quite rudimentary. The calycine

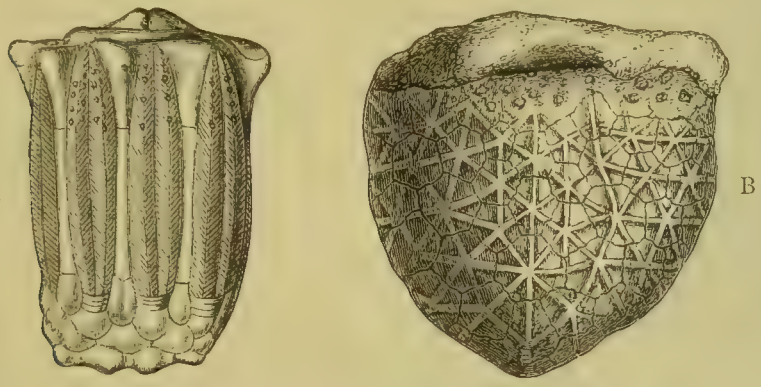


Fig. 301.—A, Calyx and arms of *Eucalyptocrinus rosaceus*, viewed from one side, of the natural size—Devonian (after Schultze); B, Calyx of *Glyptocrinus basalis*, viewed from one side, of the natural size—Ordovician (after M'Coy).

plates are ornamented with characteristic radiating ridges (fig. 301, B); the arms are uniserial; and the column is annulated or moniliform. All the species of *Glyptocrinus* appear to belong to the Ordovician period.

Family 5. *Calyptocrinidæ*.—In the remarkable forms included in this family, the calyx is regular and "monocyclic," flattened or hollowed out basally, and passing superiorly into a flask-shaped tegmen, which is narrowed above, and terminates in a centrally placed anal aperture surrounded by regularly arranged polygonal plates. The arms are, typically, twenty in number, biserial, and not projecting beyond the level of the upper limit of the calyx; and they are situated between riblike processes of the upper margin of the cup, or in special lateral niches formed by vertical outgrowths from the wall of the calyx. The members of this family are exclusively confined to the Silurian and Devonian formations, the principal genus being *Eucalyptocrinus*.

In *Eucalyptocrinus* (fig. 301, A), the calyx is inverted upon itself, the calycine cup being deeply concave at its base, so as to look like the bottom of a wine-bottle. Within this basal funnel are situated the four small basals, which are succeeded by five large primary radials. These are strongly bent, one-half of each passing up into the basal funnel, while the other half appears on the lower and lateral aspects of the cup. Two other rows of radials succeed these, the tertiary radials being unusually large, and each supporting the bases of two arms. The interradial

plates are developed in a most singular manner, so as to form a series of five linear, clavate processes, which separate and support the arms; five other precisely similar processes being borne by the axillary radials. The arms thus come to lie in deep grooves or niches in the sides of the calice, the upper surface of which they do not reach. The upper surface is completely vaulted over, and is mainly formed by the upper ends of the ten interbrachial processes just spoken of, in the centre of which is a small circular anal aperture, surrounded by five or more plates. The species of *Eucalyptocrinus* are found in the Silurian and Devonian rocks; and the Silurian genus *Hypanthocrinus* differs principally from the preceding in the fact that the base of the calyx is not funnel-shaped. The Silurian genus *Corymbocrinus* (fig. 302) has been likewise placed in the neighbourhood of *Eucalyptocrinus*, but is now considered by Wachsmuth and Springer as belonging rather to the family of the *Actinocrinidæ*. In this genus the calyx resembles that of *Eucalyptocrinus* in having a deep funnel-shaped depression at its base, but the arms are long and much divided. Lastly, the genus *Callicrinus*, also Silurian, is in most structural features closely allied to *Eucalyptocrinus*, and appears to represent an earlier phase in the development of the family.

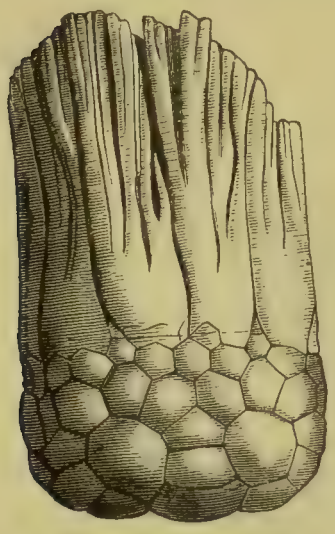


Fig. 302. — Calyx and arms of *Corymbocrinus polydactylus*. Wenlock Limestone of Britain. (After M'Coy.)

Family 6. *Crotalocrinidæ*.—In this small and remarkable family, the calyx is "dicyclic," with small underbasals and large basals. The arms are uniserial, without pinnæ, but furnished with numerous

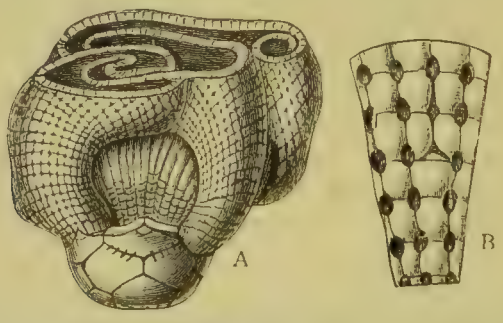


Fig. 303.—A, Calyx and arms of *Crotalocrinus Loveni*, cut across to show how the arms are rolled up; B, A portion of the network formed by the arms, enlarged. Silurian. (After J. Müller.)

branches, by the coalescence of which they become more or less extensively connected with one another laterally, generally forming wide, inrolled, foliaceous expansions. The anus, so far as known, has the form of an excentric, proboscidiform, plated tube. The

centre of the vault is occupied by five oral plates, while the ambulacral grooves of the arms and their lateral branches are covered in by small calcareous plates. The genera of this family are Silurian, but *Cleiocrinus*, if rightly referred here, is Ordovician.

The type-genus of this family is *Crotalocrinus* (*Anthocrinus*), one of the most beautiful Crinoids of the Wenlock Limestone of Gotland and Britain. The calyx consists of five small underbasals and five large basals, with a single zone of radials, while interradials are wanting, with the exception of a single small anal plate. The arms are bifurcated, and the subdivisions unite with one another by means of lateral processes, thus giving rise to a network, perforated by numerous apertures (fig. 303). The Silurian genus *Enallocrinus* is nearly allied to *Crotalocrinus*, but the arms become free towards their extremities.

Family 7. *Ichthyocrinidæ*.—In this family the calyx is "dicyclic," but the three underbasals are small, and are mostly not visible externally. The radials articulate upon one another, and are united laterally by the perisomic plates of the disc. The arms are short, bifurcating, and often in contact laterally, thus forming an upward continuation of the calyx (fig. 304, A); while pinnules are apparently wanting. The disc had open ambulacral grooves, and was covered with perisomic plates, like that of a recent Crinoid. Its central part was occupied by five oral plates, which in some species, if not in all, were separate from one another, so as to open the mouth to the exterior. The members of this family are found in the Silurian, Devonian, and Carboniferous deposits.

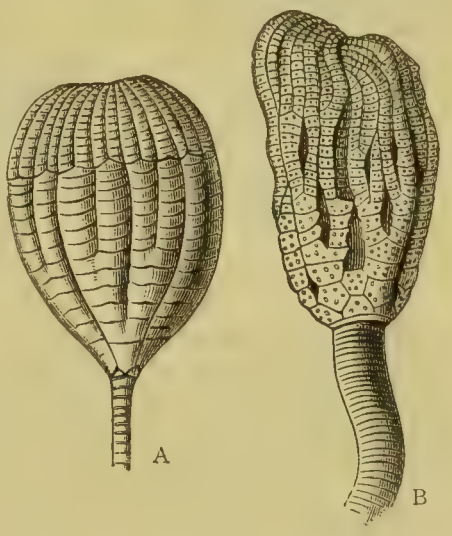


Fig. 304.—A, Side-view of the calyx of *Ichthyocrinus lævis*, from the Silurian (Niagara Limestone) of North America; B, Calyx and upper part of the column of *Taxocrinus tuberculatus*, from the Silurian (Wenlock Limestone) of Britain. (After Hall and M'Coy.)

The typical genera of the *Ichthyocrinidæ*—such as *Ichthyocrinus* itself (Silurian to Carboniferous), *Lecanocrinus* (Silurian and Devonian), and *Mespilocrinus* (Carboniferous)—are characterised generally by the imperfect separation of the calyx and arms, the latter being commonly in close apposition laterally (fig. 304, A). On the other hand, the genus *Taxocrinus* (fig. 304, B) represents a section of the family—sometimes raised to the rank of a separate family (*Taxocrinidæ*)—in which the arms are well developed and repeatedly bifurcated. The species of *Taxocrinus* are found in the Silurian, Devonian, and Carboniferous

rocks; and the genus *Forbesiocrinus*, with a similar geological range, is principally distinguished from this by the more abundant development of the interradial plates.

Family 8. *Haplocrinidæ*.—In this family the calyx is small and spheroidal, and is composed of basals and radials, underbasals being absent. The ventral surface of the calyx exhibits five large "oral" plates, forming a low pyramid, which is excavated along the sutures of the plates to receive the bases of the arms (fig. 305). There is no definite anal plate, but the anal opening perforates one of the oral plates, which is somewhat larger than its fellows. The arms are poorly developed. The family, as defined by Wachsmuth and Springer, includes only the two genera *Haplocrinus* (fig. 305) and *Allagecrinus*, of which the former is mainly if not wholly Devonian in its range, while the latter is exclusively confined to the



Fig. 305.—*Haplocrinus mespiliformis*. The calyx viewed from below, from one side, and from above, and enlarged. Devonian.

Carboniferous rocks. Both genera comprise very small Crinoids, which are in some respects simpler in their construction than the normal members of the order, and may be considered as permanently representing the larval condition of the Palæocrinoids. *Allagecrinus* is remarkable for the inequality in the size of its radials, some of which may be axillary and bear two arms. For this reason it is regarded by some authors as the type of a distinct family.

Family 9. *Symbathocrinidæ*.—In this family the calyx is small, and is composed of basals and radials only. The central portion of the ventral surface of the calyx exhibits a circle of oral plates. The arms are uniserial, exceedingly long, and folded together. The principal genera of this family are *Symbathocrinus* (Devonian and Carboniferous), *Pisocrinus* (Silurian), and *Triacrinus* (Devonian and Carboniferous).

Family 10. *Cupressocrinidæ*.—In this family the large, basin-shaped calyx is apparently of the "dicyclic" type, the underbasals being anchylosed to form a solid disc, which some authors regard as being an enlarged top stem-joint, in which case the calyx would be "monocyclic." Upon this disc rest five basals, followed by five radials, the upper edges of which are truncated and form a

horizontal line. Reposing directly upon the radials are the five first brachials, which are as wide as the radials, but are of very small vertical thickness. The arms are massive, moving as in one piece, uniserial, and undivided. They gradually diminish towards their apices, and by the accurate apposition of their edges together, form a pentagonal pyramid. The arm-plates bear numerous small and incurved pinnules, six or more on either side of each joint. These roof in the deep ambulacral grooves, which seem also to have had a definite calcareous skeleton of their own. Between the bases of the arms, in the interior of the cup, is placed a so-called "consolidating apparatus," formed of five laterally anchylosed calcareous pieces, which apparently really represent "the united muscle-plates of the radials" (P. H. Carpenter). This peculiar apparatus covers the greater part of the ventral surface of the calyx, and the mouth appears to have been placed in its centre. The column is obtusely quadrangular, annulated, and traversed by a large central canal surrounded by four smaller tubes.

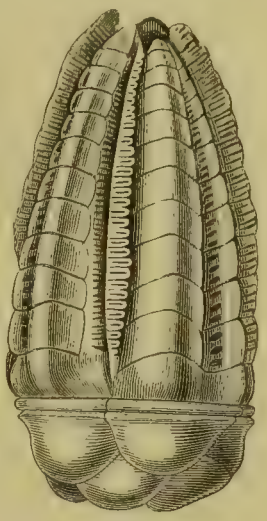


Fig 306.—Side-view of the cup of *Cupressocrinus crassus*, with the arms folded up, of the natural size. Devonian. (After Schultze.)

The only genus of this family is *Cupressocrinus* itself, the species of which are exclusively Devonian, and appear to have been wholly confined to the European area. The characters of the genus need not be more fully discussed, the principal ones having been mentioned in the diagnosis of the family.

Family 11. *Gasterocomidæ.*—In this family the calyx (fig. 307) is small and spheroidal, and is typically dicyclic, the underbasals



Fig. 307.—*Gasterocoma antiqua*, from the Devonian rocks of the Eifel, enlarged twice. *a*, The calyx viewed from the side; *b*, The anal aspect of the calyx; *c*, The ventral surface of the calyx. (After Schultze—copied from Zittel.)

being usually represented by a simple pentagonal plate. This plate may, however, be merely an enlarged top stem-joint (as in *Cupressocrinus*), and Zittel regards *Nanocrinus* as being monocyclic. There are five basals, and generally an equal number of radials, with one

or more interradials in the anal interradius. In *Nanocrinus*, however, there are only four arm-bearing radials, one of which is axillary. In the type-genus *Gasterocoma*, one of the basals is notched for the anal opening, which is situated between it and the first anal plate. The arms are recumbent or widely divergent, and the stem is generally four-sided, and is perforated by four canals, surrounding, or confluent with, a larger central canal. The two principal genera of this family are *Gasterocoma* (*Epactocrinus*) and *Nanocrinus*, both of which are found in the Devonian deposits of Europe.

Family 12. *Hybocrinidæ*.—The members of this small family exhibit embryonic characters, and have a "monocyclic" base, with imperfectly developed radials, and a very small ventral sac. The basals are five in number, and are very large. The arms are simple and without pinnules; and one or more of them may be undeveloped, or only represented by recurrent ambulacra which run over the outer surface of the calyx. The genera included by Wachsmuth and Springer in this family are *Hybocrinus*, *Hybocystites*, *Hoplocrinus*, and *Baerocrinus*, all of which are confined to the Ordovician rocks.

Family 13. *Heterocrinidæ*.—In this family are comprised Palæocrinoids with a relatively large ventral and small dorsal development of the calyx. The basis, as in the preceding family, is "monocyclic," thus differing from that of the *Cyathocrinidæ* and *Poteriocrinidæ*, in which underbasals are present. The arms are much more developed than in the *Hybocrinidæ*, and are furnished with long pinnules. The principal genera are *Heterocrinus* and *Stenocrinus*, both of which are found in the Ordovician rocks of North America.

Family 14. *Anomalocrinidæ*.—In this family the only genus is *Anomalocrinus*, the species of which are found in the Ordovician rocks of North America. The calyx in this genus is large and depressed, with a "monocyclic" basis. The pinnules of the arms are not given off alternately from opposite sides (as in Crinoids generally), "but from every successive joint on one side at a time, from one bifurcation to the next, where they change on both rami to the opposite" (Wachsmuth and Springer).

Family 15. *Belemnocrinidæ*.—The only genus included in this family is the *Belemnocrinus* of the Carboniferous Limestone of North America. In this genus, the basis is "monocyclic," with no underbasals, but with relatively large basals. The ventral side of the calyx is well developed, but the visceral cavity is extremely small. There is an anal plate placed in a line with the radials. The anal proboscis is large and porous. Lastly, the pinnules of the arms are given off regularly at every second or third joint, and not alternately from all the brachials. According to Wachsmuth and Springer, the

genus forms a connecting-link between the *Heterocrinidæ* and the *Cyathocrinidæ*.

Family 16. *Cyathocrinidæ*.—In this important family of Crinoids, the calyx is irregular, and is of the "dicyclic" type, consisting of five underbasals (fig. 308, *b*), five basals (*p*), five primary radials (*r*), and from one to three anal interradials (*a*). The ventral surface of the calyx is mainly formed by the large interradial plates, between which are the ambulacral grooves, roofed over with small calcareous plates (fig. 297). The arms are uniserial, long, repeatedly bifurcated

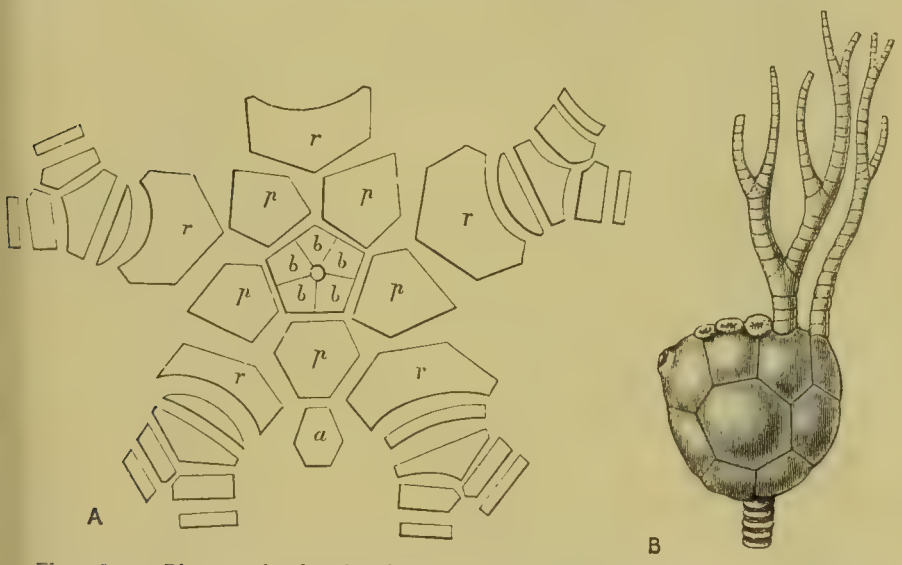


Fig. 308.—A, Diagram, showing the dissected calyx of *Barycrinus* (after Hall): *b*, Underbasals; *p*, Basals; *r*, Lowest of the three radials ("primary radials"); *a*, Anal plate. B, Calyx and part of the arms of *Cyathocrinus planus*, of the natural size. Carboniferous.

(fig. 309), and without true pinnules. The family of the *Cyathocrinidæ* is closely allied to that of the *Poteriocrinidæ*, but the arm-joints are differently articulated in the two, and the arms are repeatedly bifurcated in the former group; whereas in the latter the arms may remain simple after the first bifurcation, or branch irregularly, and they, further, carry pinnules. The range of the *Cyathocrinidæ* in time is from the Silurian to the Permian inclusive.

The principal genus in this family is *Cyathocrinus* itself (fig. 309), which ranges from the Silurian to the Permian, but attains its maximum development in the Carboniferous Limestone. In this genus the calyx is small and basin-shaped, with long, frequently divided arms. The ventral side is slightly convex, and a plated anal tube is present. The column is round, and is composed of very narrow articulations, which are perforated by a five-angled neurovascular canal. *Barycrinus*, of the Carboniferous rocks of North America, is nearly related in most respects to *Cyathocrinus*; while *Dendrocrinus* (Ordovician), *Carabo-*

crinus (Ordovician), and *Homocrinus* (Silurian and Devonian) are other leading genera of this family.

Family 17. *Poteriocrinidæ*.—In this family the calyx is "dicyclic," and is essentially similar to that of *Cyathocrinus*, consisting of five underbasals, five basals, five primary radials, and from one to five interradials (fig. 291). The arms are simple or bifurcated, and carry long pinnules. The ventral surface of the calyx is elevated and convex, and a greatly developed anal tube or proboscis is usually present (fig. 298). The genera of this family appear to be principally, if not wholly, confined to the Devonian and Carboniferous rocks, by far the larger number of forms belonging to the latter.

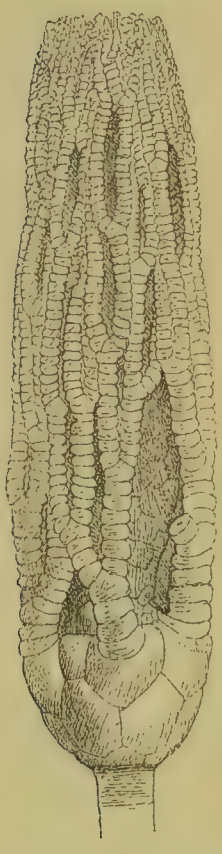


Fig. 309.—Side-view of the calyx and arms of *Cyathocrinus longimanus*, of the natural size, Silurian. (After Angelin — copied from Zittel.)

The principal genus of this family is *Poteriocrinus* itself (fig. 298), which is closely allied to *Cyathocrinus*, from which it is distinguished principally by the more elevated form of the ventral sac, the great development of the anal tube, and the structure of the arms. These latter organs may be simple or branched, but in either case are provided with pinnules, while the radials are truncated superiorly, where they articulate with the brachials. On the other hand, in *Cyathocrinus* the arms are without pinnules, and the first radials (fig. 308, *r*) articulate with the second by means of horse-shoe-shaped facets. The species of *Poteriocrinus* are mainly Carboniferous, but a few forms are known from the Devonian rocks. Closely allied genera are *Zeacrinus* (Carboniferous) and *Scaphiocrinus* (Carboniferous and Devonian).

Family 18. *Astylocrinidæ*.—The calyx in this family is *free*, the peduncle of the larva being evanescent; and it is composed of firmly united massive plates (fig. 310). Typically, the calyx is "dicyclic," but *Edriocrinus*, if rightly referred here, has no underbasals. There are two cycles of radials, the second of which is axillary, and the arms are provided with long pinnules. Anal interradial plates are developed, and the dorsal side of the calyx does not carry cirri. The type-genus of this family is *Agassizocrinus* (= *Astylocrinus*), which is found in the Carboniferous Limestone of North America. The genus *Edriocrinus*, from the Silurian rocks of North America, has also been provisionally placed in this family by Wachsmuth and Springer.

In *Agassizocrinus* (figs. 310, 311) the calyx was attached in its early condition by a larval peduncle, but the adult was free. The underbasals

become united to form an almost solid disc, which is slightly hollowed above, and exhibits a group of pits, which probably lodged extensions of the "chambered organ." The Silurian genus *Edriocrinus* was also free in its adult condition, but underbasals are wanting, and it possesses other peculiarities as well.

Family 19. *Catillocrinidæ*.—In this small family, the calyx is of small size and of the "monocyclic" type. The radials are remarkably unequal in point of size, two of them being greatly developed, and forming the larger part of the margin of the calyx. These carry a much larger number of the arms than the three small radials. The arms are simple, uniserial, and long, and the column is round.

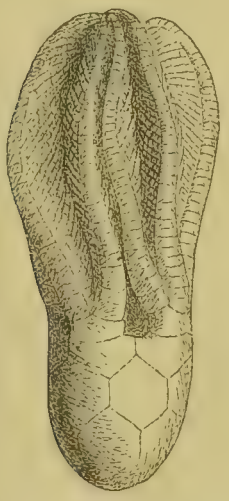


Fig. 310.—Side-view of a complete example of *Agassizocrinus dactyliformis* (=*Astylocrinus lævis*, F. Roemer). Carboniferous, North America. (After Meek and Worthen.)

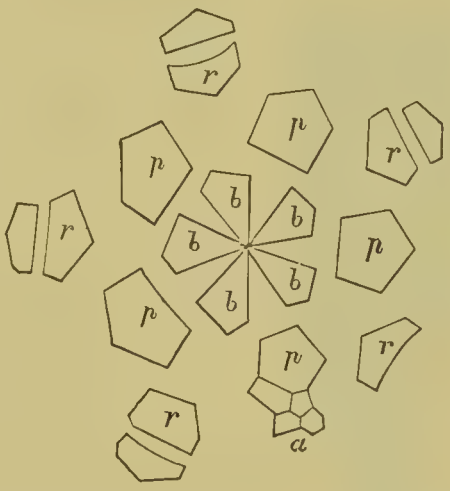


Fig. 311.—Dissected calyx of *Agassizocrinus*. *b*, Underbasals; *p*, Basals; *r*, Radials; *a*, Anal plates. (After Hall.)

The type-genus is *Catillocrinus*, the geological horizon of which is the Carboniferous rocks of North America.

Family 20. *Calceocrinidæ* (= *Cheirocrinidæ*).—This family includes only the aberrant genus *Calceocrinus* (= *Cheirocrinus*), which ranges from the Ordovician to the Carboniferous. In this genus the small and irregular calyx, with its crown of arms, is fixed in such a way as to hang downwards from the summit of the column. The calyx is "monocyclic," and there are only three basals, which, in the natural position of the cup, are situated posteriorly. The radials are of unequal size, only three of them bearing arms. The basals and radials are united by ligaments and muscles, so that a distinct articulation is formed at this point in the cup. The arms are bifurcated, and those on the posterior side are the strongest.

Division B. Neocrinoidea.

This division of the *Crinoidea* corresponds with the *Articulata* of Müller (with the addition of the genera *Marsupites* and *Uintacrinus*), together with the *Costata* of the same author. As defined by Dr P. Herbert Carpenter, the forms included in the *Neocrinoidea* possess a relatively minute, usually symmetrical, regularly pentamerous calyx, the arms being in general greatly developed. There are, as a rule, five equal and similar basals, and five also equal and similar radials. Underbasals are rarely present (*Encrinus*, *Extracrinus*, and *Marsupites*). Interradials are rarely developed, and, when present, no special "anal" interradius (except in *Thaumatocrinus* alone) is recognisable. The higher radials do not enter largely into the composition of the calyx, and are usually more or less movable, being generally united to the succeeding plates by a muscular articulation. The ventral surface of the calyx is not concealed by an external canopy or vault of calcareous plates, but the aperture of the mouth, with the ambulacral grooves converging to it, is exposed to view. The ambulacral grooves may be more or less roofed in by calcareous plates, and "oral" plates, when present, "may be limited to larval existence, or remain through life partially covering the peristome, but capable of being separated so as to open the mouth to the exterior" (P. H. Carpenter). All the Neocrinoids are Secondary, Tertiary, or Recent, no Palæozoic representatives of the division being at present known.



Fig. 312. — *Encrinus liliiformis*. Muschelkalk. The lower figure shows the articulating surface of one of the column-joints.

Family 1. *Encrinidæ*.—In this family the calyx is shallow and basin-shaped, with a "dicyclic" basis. There are five underbasals, which are of very small size, and are concealed by the uppermost joint of the column. These are succeeded by five large basals, followed in turn by five radials, the whole of these plates being firmly united by suture. The primary radials are followed by two others, the second of which is axillary and bears two arms, which sometimes fork again, so that there are ten, or, rarely, twenty divisions in all. The arms (fig. 312) are often biserial, are abundantly furnished with pinnules, and form by their apposition a kind of pyramid. The upper column-joints (fig. 312) are generally alternately large and small. The joint-surfaces are furnished with

radial ridges, and each exhibits in the centre a small round or pentagonal neurovascular canal (see the lower figure in fig. 312). Lastly, the visceral mass was enclosed in a plated perisome essentially similar to that of the recent Crinoids.

The only clearly established genus belonging to this family is *Encrinus* itself, all the species of which are Triassic. A well-known species of this genus is the Lily-encrinite (*E. liliiformis*, fig. 312), the heads of which are not very rare in some localities in the Muschelkalk of Germany.

Family 2. *Eugeniacrinidæ*.—In this singular family, the calyx (fig. 313) is apparently composed only of primary radial plates, which rest directly upon the enlarged uppermost joint of the column. Basals have not been detected, but it is probable that they were present in a rudimentary form. There are two additional rows of radials, which bear ten uniserial arms, and the base of the column is expanded, and serves to cement the animal to foreign bodies. The geological range of the family is restricted to the Jurassic and Cretaceous rocks.



Fig. 313.—*Eugeniacrinus caryophyllatus*, without the arms, restored. Jurassic rocks. (After Fraas—copied from Zittel.)

The principal genus of this family is *Eugeniacrinus* itself (fig. 313), which occurs in the Jurassic and Cretaceous deposits of Europe. The column-joints and clove-shaped calyx of species of this genus are not uncommon, but the arms have never been found attached to the cup, and no example of a complete calyx has yet been detected.

Family 3. *Holopidæ*.—In this aberrant family the calyx is without a column, and is firmly adherent to foreign bodies by the under surface of the wide cup. The basals are fused with one another, and usually with the radials also, in which latter case the presence of distinct basals can only be inferred. The arms (where known) are thick, massive, and spirally inrolled.

In the recent genus *Holopus* the basals and radials are "completely anchylosed into an asymmetrical tube-like calyx, which is fixed by an irregularly expanded base" (P. H. Carpenter). Allied to this extraordinary living type are a few fossil forms from the Mesozoic and later Tertiary deposits. Of these the genera *Cotylecrinus* (*Cotylederma*) and *Eudesicrinus* are confined to the Lias; while *Cyathidium* is found in the late Cretaceous deposits (Faxoe Limestone) and in the Eocene Tertiary.

Family 4. *Hyocrinidæ*.—This family includes only the living

genus *Hyocrinus*, which is in some respects related to the Palæocrinoids. In this genus the calyx-plates are thin, and the cup consists of both basals and radials, the former being only three in number. The radials are five in number, and each carries a single undivided arm. The arm-joints are united by "syzygy" into groups of two or three, the terminal joint of each group bearing a long pinnule. There are five large "oral" plates round the mouth. The stem consists of short cylindrical joints, the articular surfaces of which are simple or slightly striated.



Fig. 314.—*Apiocrinus Roissyanus*. Middle Oolite (Jurassic).

Family 5. *Plicatocrinidæ*. — This family includes only the Jurassic genus *Plicatocrinus*, which is considered by Zittel as nearly allied to, or identical with, *Hyocrinus*. Basal plates are, however, said to be absent; while the arms are short, and the joints are not united by "syzygy," and are provided with short pinnules.

Family 6. *Apiocrinidæ*. — In this family the calyx is regular, and the upper stem-joints are, typically, wider than those below, the upper part of the column thus passing gradually into the base of the cup. The basals are five in number, and are surmounted by three cycles of radials, each cycle being normally pentamerous. The stem is expanded at its base for attachment to foreign bodies, or is furnished with branching roots or cirri (fig. 314), and the apposed faces of its component joints are marked with radial striæ. The earliest types of this family (*Apiocrinus* and *Millericrinus*) appear in the Jurassic rocks, and became extinct in the Lower Cretaceous period.

In the genus *Apiocrinus*, comprising the so-called "Pear-encrinites," there is a long cylindrical stem, rooted to foreign bodies by an expanded base (fig. 314). The upper joints of the stem are narrower, as regards vertical height, than the lower ones, while they are widened out laterally, so as to pass gradually into the massive pyriform cup. The uppermost joint of the stem is much enlarged, and carries the five basals, which are in turn succeeded by three rows of radials. The species of *Apiocrinus* are found in the Jurassic and Lower Cretaceous rocks. In the genus *Millericrinus*, with a very similar geological range, the upper stem-joints are only

very gradually widened out, and the top one is not very greatly larger than those below it.

Family 7. *Bourgueticrinidæ.*—In this family the calyx is very simple, consisting of five basals and five radials. The stem-joints are dice-box-shaped, their faces bearing transverse ridges with fossæ at their sides which lodge the interarticular ligaments. The stem is attached below by a branching root or by radicular cirri, and there are five or ten slender arms, the joints of which are united in pairs, with a pinnule on the distal joint of each pair only. The disc bears five oral plates of variable size, and the brachial ambulacra have two rows of covering-plates.

This family differs essentially from the *Apiocrinidæ* in the relatively small size of the calycular cavity and in the more or less dice-box-shaped character of the stem-joints. In the type-genus *Bourgueticrinus* there is a small pyriform calyx, passing gradually downwards into the thickened upper part of the stem, the top joints of which are much enlarged, while it is fixed below by a root-like prolongation. *Bourgueticrinus* is essentially a Cretaceous genus, but has been described as occurring both in Jurassic and in Tertiary strata, solely, however, on the very uncertain evidence afforded by stem-joints. The family is represented by two living genera. *Bathycrinus* ranges from 1000 to 2400 fathoms in the Atlantic, but is not yet known in the fossil state; while *Rhizocrinus*, which occurs at smaller depths, ranges back to the Eocene Tertiary. In the former type the basals are small and firmly united, while the radials are long and comparatively free, and there are ten arms. On the other hand, *Rhizocrinus* has long basals and short, closely united radials, as in *Bourgueticrinus;* while there are but five arms, the joints of which are united by "syzygy," only the upper joint of each pair bearing a pinnule. In both genera the upper stem-joints are thin and discoidal, while the ambulacral furrows of the arms and pinnules are protected by delicate calcareous plates. The disc of *Rhizocrinus* is, further, covered by large "oral" plates, which are much reduced or absent in *Bathycrinus.*

Family 8. *Pentacrinidæ.*—This family is defined by Dr P. H. Carpenter as comprising forms in which the calyx is small relatively to the stem and arms, and is "composed of five basals and five radials, with underbasals in one genus. The rays divide from one to eight times. The stem bears verticils of cirri at intervals. Two joints are united by syzygy at each node, to the upper one of which the cirri are articulated. The internodes are traversed by five ligamentous bundles, which are interradially disposed, and give rise to a more or less petaloid figure on the joint-faces. No root nor radicular cirri." The range of the family is from the Trias to the present day.

The type-genus of this family is *Pentacrinus* itself, which has the geological range of the family. In this well-known genus (fig. 289) the joint-faces of the pentagonal stem are marked by crenated ridges

arranged in a floriform manner, each petaloid sector having from five to eight large teeth at the sides. There are only three radials, and the arms rarely divide more than thrice. The genus *Metacrinus*, only known by living forms, differs from *Pentacrinus* chiefly in the possession of from four to six radials, the characters of the joint-faces being the same in both genera. Lastly, the Mesozoic genus *Extracrinus* (fig. 290) is separated from *Pentacrinus* by the possession of a ring of underbasals, and by the much more frequent subdivision of the arms. The faces of the stem-joints in this genus are also different, the petaloid sectors being linear, and having delicately crenulated edges. In all three genera the visceral mass is surrounded by a plated perisome, which unites the lower part of the rays and arms.

Family 9. *Marsupitidæ*.—This family comprises *free* Crinoids, in which the larval peduncle is lost in the adult. A "centrodorsal" plate is present, but this does not bear cirri. The calyx may be monocyclic or dicyclic, and there are no definite interradial plates. The only genera included in this family are *Marsupites* and *Uintacrinus*, both of which are confined to the Cretaceous period.



Fig. 315.—Side-view of the calyx and bases of the arms of *Marsupites ornatus*, from the Chalk.

The genus *Marsupites* comprises the so-called "Tortoise-encrinites" of the Chalk, and is characterised by the possession of a globular calyx, composed of large thin plates, carrying bifurcated uniserial arms. The calyx is dicyclic, the underbasals, five in number, surrounding a central pentagonal plate, which has usually been regarded as an enlarged top stem-joint ("centrodorsal"). There is, however, reason to think that it is rather homologous with the suranal plate of *Salenia*, and therefore a "dorsocentral" plate. There are five basals and three rows of radials, but regular interradials are not developed. The ventral surface of the calyx is vaulted, and covered with small calcareous plates; and the anus is sub-central. The genus *Uintacrinus* resembles *Marsupites* in its general form, and in the possession of a pentagonal "centrodorsal" (?) which does not carry cirri. On the other hand, the globular calyx is monocyclic, and there are ten arms, the bases of which are united laterally by numerous perisomic plates, as in the *Pentacrinidæ*.

Family 10. *Comatulidæ*.—This family of Crinoids comprises the "Feather-stars," all of which (except *Thiollericrinus*) lose the larval peduncle, and are therefore free in the adult condition (fig. 284). The base of the calyx is closed by a "centrodorsal" plate (fig. 285, *cd*), which represents the enlarged top stem-joint, and upon which jointed cirri are developed. The calyx is apparently "monocyclic," but underbasals have recently been discovered in the larva

of the Rosy Feather-star, and there are grounds for believing that their presence is characteristic of the family. They never reach any great size, however, and fuse at an early period with the enlarged top stem-joint or "centrodorsal." The basals are very generally rudimentary, being reduced to a small "rosette-plate," concealed between the centrodorsal and the primary radials. In *Atelecrinus* and *Thaumatocrinus*, however, and in most fossil *Comatulæ*, the basals persist and are visible externally. There are three, or, rarely, two cycles of radials; and, except in *Thaumatocrinus*, definite calyx-interradials are not developed. There are five or ten arms, which are either simple or more or less divided. A large number of living forms of the "*Comatulæ*" are known, with a very wide range in space. As regards their distribution in time, the earliest types of the Feather-stars are found in the Jurassic

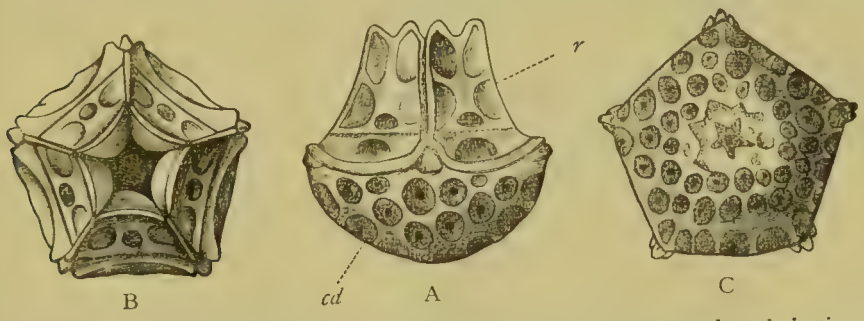


Fig. 316.—Centrodorsal (*cd*) and radial pentagon (*r*) of *Antedon incurva*, enlarged six times. Cretaceous (Upper Greensand). A, Side-view; B, View from above; C, View from below. (After P. H. Carpenter.)

rocks (*Antedon*, *Actinometra*, &c.), and there are also various Cretaceous and Tertiary types. The parts most commonly preserved in a fossil condition are the centrodorsal plate and radial pentagon (fig. 316); and upon remains of this nature, before their true character was understood, the generic name of *Solanocrinus* ("*Glenotremites*") was founded. The names of *Allionia*, *Ganymeda*, &c., were also based upon the isolated centrodorsals of fossil *Comatulæ*.

The extensive genus *Antedon* possesses a central or subcentral mouth and ten or more arms, while the basals of the recent species form a "rosette," and are invisible externally. The earliest fossil species appear in the Lias. *Eudiocrinus* resembles *Antedon*, but has only five arms. The genus is represented by a single Cretaceous form, but living types are known. *Actinometra* differs from *Antedon* in the fact that the mouth is excentric or marginal in position. The genus ranges from the Jurassic period to the present day. Lastly, in the Jurassic and Cretaceous genus *Thiollericrinus*, the centrodorsal plate exhibits a cavity which is usually filled by the first joint of the persistent stem, the lower

joints of which are dice-box-shaped. The genus has therefore been compared to an *Antedon* with a *Bourgueticrinus* stem.

Family 11. *Saccocomidæ.*—This remarkable family comprises only the single genus *Saccocoma*, which is represented by one species (*S. pectinata*, fig. 317) only, from the Upper Jurassic rocks (Litho-



Fig. 317.—*Saccocoma pectinata*, from the Upper Jurassic of Bavaria. The left-hand figure shows the complete organism, with the arms inrolled.

graphic Slates) of Bavaria. In this singular genus, the organism is free, the larval peduncle being evanescent. The calyx is composed of a single minute basal supporting a cycle of five, thin, closely united radials, ornamented externally with ten radiating ribs, and the ventral surface is occupied by five oral plates. There are

five arms, which bifurcate once, and have the power of rolling up. The arms carry a few long pinnules like those of *Hyocrinus*, and possess small undivided spine-like processes. The skeletal tissue is throughout peculiar in not being dense, but in having a tolerably loose reticulated structure. The characters of *Saccocoma* are so peculiar, that the genus was placed by Müller in a separate division of Crinoids, to which he applied the name of *Costata*.

APPENDIX.

Since the preceding pages were written, some important discoveries have been made respecting the nature of the ventral covering in *Encrinus* and *Taxocrinus*, the latter genus having a plated disc exactly like that of a Neocrinoid, with open ambulacra and an exposed mouth surrounded by five oral plates. There can be little doubt that the other *Ichthyocrinidæ* were essentially in the same condition: while *Encrinus* proves to be very closely allied to the Carboniferous *Poteriocrinidæ*, such as *Erisocrinus* and *Stemmatocrinus*.

Under these circumstances, it is no longer possible to regard the *Neocrinoidea* and *Palæocrinoidea* as well-defined primary groups, though the names may be conveniently retained as expressing a general stratigraphical distinction between the older and the younger Crinoids. Messrs Wachsmuth and Springer have already suggested the outlines of a new classification which, with slight modification by Dr P. H. Carpenter—to whom the author is indebted for the present note—will probably result in something like the following scheme.

Order I. Coadunata.

Crinoids in which the interradials, where present, are incorporated into the calyx, the latter generally also including the higher radials, which are immovably united by suture; while an anal system is well developed. The mouth and ambulacra are subtegminal, the centre of the vault being occupied by five oral plates, and the arms are usually biserial.

Sub-order I. Camerata.

Families—Actinocrinidæ, Rhodocrinidæ, Reteocrinidæ, Glyptocrinidæ, Melocrinidæ, Platycrinidæ, Hexacrinidæ, Barrandeocrinidæ, Calyptocrinidæ.

Sub-order II. Reticulata.

Family—Crotalocrinidæ.

Order II. Inadunata.

Crinoids in which the arms are free from the first radials. The calyx generally has an anal side, and frequently a dicyclic base. Interradials may or may not be present. The mouth may be concealed beneath an oral pyramid, or in the centre of a plated disc with open ambulacra.

Sub-order I. Larviformia.—Interradial and anal plates rarely present. Base monocyclic: arms uniserial. Ambulacra closed, and mouth concealed by an oral pyramid.

Families—Haplocrinidæ, Symbathocrinidæ, Cupressocrinidæ, Gasterocomidæ.

Sub-order II. Fistulata.—Interradial and anal plates generally well developed. Base usually dicyclic, and arms often biserial. Oral plates generally reduced, and the calyx covered by a plated perisome which often bears open ambulacra. The posterior interradius may be greatly developed to form the ventral sac or anal proboscis.

Families — Hybocrinidæ, Heterocrinidæ, Anomalocrinidæ, Belemnocrinidæ, Cyathocrinidæ, Poteriocrinidæ, Encrinidæ, Astylocrinidæ, Catillocrinidæ, Calceocrinidæ.

Order III. Articulata.

Crinoids in which the higher radials are more or less movably articulated on one another, though often united laterally by the plated perisome of the disc. The ambulacra are generally open and the mouth exposed, though often surrounded by oral plates. Interradial and anal plates rarely present: arms uniserial.

Sub-order I. Impinnata.

Family—Ichthyocrinidæ.

Sub-order II. Pinnata.

Families—Pentacrinidæ, Comatulidæ, Apiocrinidæ, Bourgueticrinidæ, Eugeniacrinidæ, Holopidæ, Marsupitidæ, Plicatocrinidæ, Hyocrinidæ, Saccocomidæ.

CHAPTER XXVI.

PELMATOZOA—continued.

CYSTOIDEA AND BLASTOIDEA.

Class II. Cystoidea.

The Cystideans are an extinct group of Echinoderms in which *the body (or "calyx") is spherical or ovate, and is enclosed in a case composed of more or fewer calcareous plates, which are usually united by suture but irregularly arranged, and do not exhibit perfect radial symmetry. The plates of the calyx are in general pierced by more or less numerous pores, which probably communicated with internal organs, and which may be regarded as almost certainly connected with the function of respiration. A jointed column may be present or absent.*



Fig. 318.—*Hemiscosmites pyriformis*, one of the Cystideans. The right-hand figure shows the upper surface of the calyx.

The upper surface of the calyx usually shows radiating ambulacral grooves, a central oral aperture, and a lateral anal (?) *opening, with sometimes a small ovarian* (?) *opening. Arms are imperfectly developed, or may be wanting.*

In general form the Cystideans are globular, oval, pear-shaped,

conical, or subcylindrical, and they generally resemble the Crinoids in consisting of a stem or "column" and a body or "calyx." The stem is sometimes long (as in *Caryocrinus*); but it is usually feebly developed, and often attenuated towards its base, sometimes terminating in a single long spindle-shaped piece (*Lepadocrinus*, fig. 326, D), in which case it probably did not serve as an organ of attachment. In other cases the stem is rudimentary (as in *Echinosphærites*) or it may be even absent altogether, the organism being then mostly attached to foreign objects by the base of the calyx, or, rarely, free.

The calyx is composed of a number of polygonal plates, which usually exhibit no marked radial disposition, though they are sometimes of limited number and arranged according to a definite plan. In other cases the calyx-plates are indefinite in number and arrangement; and in some forms the number and arrangement of the plates may be definite on one side of the calyx and indefinite

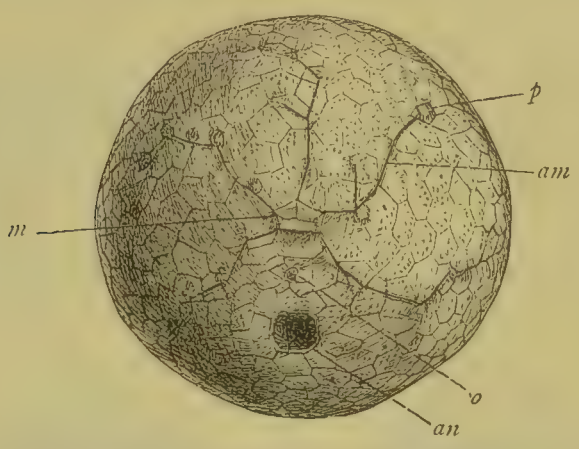


Fig. 319.—Upper surface of the calyx of *Glyptosphærites Leuchtenbergi*, from the Ordovician rocks of Russia. *m*, Mouth, covered by the oral plates; *am*, Ambulacral grooves; *p*, Socket for one of the armlets; *an*, Anus, without its covering-plates; *o*, Supposed ovarian aperture.

on the other. The base of the calyx is usually readily recognised by the presence of the articular surface for the top joint of the stem, or by being fixed to some foreign object; and the upper surface generally shows two or three openings, the nature and functions of which have been much disputed. One of these openings is central or subcentral in position (319, *m*), and is often protected in well-preserved specimens with a covering of five small plates, representing the orals of the Crinoids, while it forms the point of convergence of from two to five, simple or branched grooves which run over the ventral surface of the calyx (*am*). These grooves clearly correspond to the "ambulacral grooves" or "food-grooves" of the Crinoids, and there can therefore be no doubt that the aperture in

question is the mouth. A second aperture (fig. 319, *an*) is placed excentrically, usually on the upper surface of the calyx, and in good specimens is furnished with five or six triangular calcareous plates, which are arranged to form a sort of cone or "valvular pyramid," and which serve for the closure of the opening. It is not necessary to discuss the various views which have been put forward as to the functions of this orifice, but there is every reason to believe that it is really the anus. In many cases there is a third opening, which is always of small size and always placed near the mouth (fig. 319, *o*). This aperture has been commonly regarded as being of the nature of an "ovarian" aperture or genital pore.

In well-preserved examples, the upper surface of the calyx commonly exhibits simple or branched grooves (fig. 319, *am*), which radiate from the mouth, and obviously are of the nature of "ambulacral grooves" or "food-grooves." In some cases, as, for example, in *Callocystites* (fig. 320) and in *Lepadocrinus* (fig. 326, c), the ambulacral groove is bordered on each side with a row of delicate jointed pinnulæ, which are also grooved on their ventral faces. In such cases, the ambulacral grooves may be looked upon as representing recumbent arms which have become soldered down to the surface of the calyx. In cases where the ambulacral groove is bordered by a single row of pinnules, the arm may be supposed to be fastened down to the calyx by one of its sides instead of by the dorsal surface. In other Cystideans the upper surface of the calyx exhibits irregularly scattered articular facets, which, in the perfect condition, served for the attachment of small unbranched jointed filaments. These may be regarded as of the nature of "armlets" or simple arms, rather than as pinnulæ. They are seen in such genera as *Glyptosphærites* (fig. 319, *p*), *Caryocrinus* (fig. 326, A), and *Pleurocystites* (fig. 326, B), and they can be sometimes shown to possess a ventral groove, which is provided with small calcareous covering-plates. Lastly, in the genus *Comarocystites* there are four free arms, which differ from the structures just spoken of, and agree with the arms of the Crinoids generally, in being provided with lateral pinnæ.

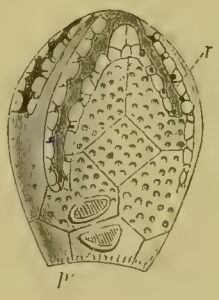


Fig. 320.—Side-view of the calyx of *Callocystites Jewettii*, from the Silurian of North America, showing the ambulacral grooves (*r*) and the origins of the pinnules on the sides of these. *p*, Pore-rhombs. (After Hall.)

In some forms of the Cystideans (*Cryptocrinus*, *Malocystites*, &c.) the plates of the calyx appear to be completely imperforate. In the majority of cases, however, the walls of the calyx are more or less extensively perforated by pores or fissures, which usually open directly on the outer surface of the body, but are in other cases

closed by an exceedingly thin calcareous membrane, while they invariably traverse the entire thickness of the plates. Their arrangement differs much in different types of the Cystideans, and they afford therefore important evidence in classification. In certain forms (such as *Glyptosphærites*, *Gomphocystites*, &c.) the pores are conjugate, or are united in pairs, the individual plates possessing

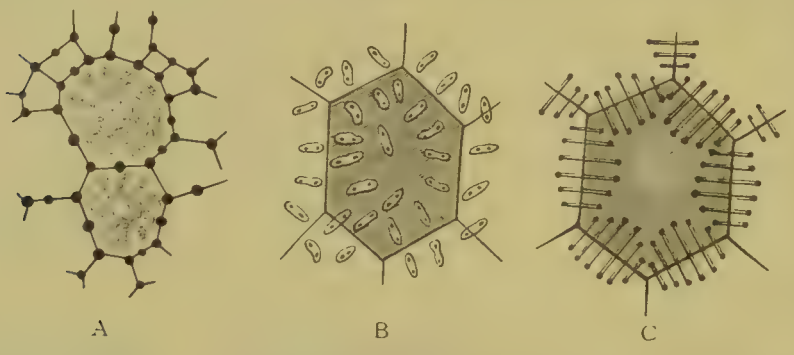


Fig. 321.—A, Part of the calyx of *Eocystites? longidactylus*, from the Cambrian rocks of North America, enlarged, showing pores passing between adjoining plates; B, Plate of *Glyptosphærites Leuchtenbergi*, enlarged, showing double pores; C, Plate of *Echinosphærites aurantium*, showing diffused pore-rhombs, enlarged, from the Ordovician rocks of Russia. (A is after Walcott.)

several of such pairs (fig. 321, B). In other forms, the pores are arranged in rows, a row on one plate being united by grooves or fissures, sometimes on the exterior of the calyx or at other times on its interior, with a corresponding row on an adjoining plate. These rows of connected pores (fig. 322) are arranged so as to form lozenge-shaped or rhombic figures; in such a manner that one-half of

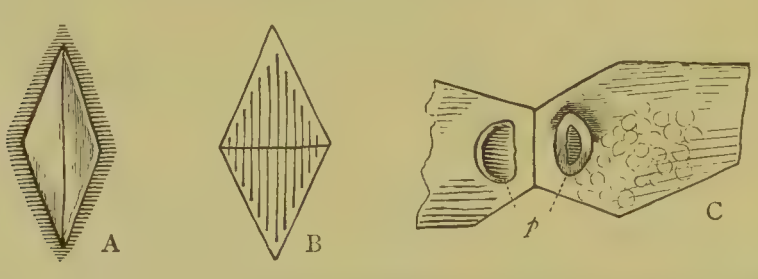


Fig. 322.—A, Pore-rhomb of *Glyptocystites multiporus* (Billings); B, Pore-rhomb of *Pleurocystites* (Billings); C, Two plates of *Callocystites Jewettii* (Hall), showing the pore-rhombs (*f*). All enlarged.

each rhomb belongs to one plate and the other half to its contiguous neighbour, while the grooves connecting the two component rows of pores pass across the line of suture between the two plates, either externally or internally. In some types, as in *Echinosphærites* (fig. 321, C) and *Caryocystites*, these "pore-rhombs" are very numerous, and are present upon nearly all the plates of the calyx. In other

cases (as in *Caryocrinus* and *Hemicosmites*) they are only developed on the side-walls of the calyx, and are absent from its upper surface. In other cases, again, as in *Pleurocystites* (fig. 326, B) or *Callocystites* (fig. 322, C), the pore-rhombs, or "pectinated rhombs," as they have been often termed, are comparatively few in number, and their component halves not only stand on contiguous plates, but may be separated externally by an interval.

It would seem extremely probable that the differences in the form and arrangement of the pores in different groups of Cystideans, which have been pointed out above, are really an indication of a fundamental difference in the nature and function of these structures. In those Cystideans which possess "pore-rhombs" (*Rhombiferi*), there seems no reason to doubt that these structures were connected with internally-placed, folded tubes similar to the "hydrospires" of the Blastoids, and that they acted as respiratory organs. On the other hand, it has been suggested by Lovén, with much probability, that the linked pores of *Glyptosphærites* and its allies (*Diploporitidæ*) were connected with the ambulacral system, and that, like the pores in the test of the Urchins, they were occupied by pedicels. On this view, "hydrospires" are wanting in the types in question, and the function of respiration would be discharged by the tube-feet. If this suggestion be accepted, the Diploporous Cystoids would be comparable to the Sporadiporous Holothurians or to such Urchins as *Melonites*. They would, however, differ from the Urchins generally in the want of definite radial symmetry in the plates of the test, and also in the fact that the pores for the tube-feet perforate the plates of the *interambulacral* areas, instead of being confined to the ambulacral areas only.[1] The Cystoids (*Aporitidæ*) in which neither pores nor "pore-rhombs" are developed, occupy a dubious position from a systematic point of view. They differ widely from the preceding groups in some respects, and it is possible that they may ultimately find a place elsewhere.

As regards their *distribution in time*, the Cystideans are not only wholly extinct, but they are entirely restricted to the Palæozoic period, ranging from the Cambrian period to the Carboniferous Limestone, but attaining their maximum of development in deposits of Ordovician age. The few Cambrian forms which have hitherto been detected are only known from imperfect examples, and their precise structure is incompletely understood. Upon such remains have been founded several genera (*Eocystites*, *Trochocystites*, *Protocystites*, &c.), but these do not at present admit of precise definition.

[1] In such Urchins as *Scutella* (fig. 240) the branches of the ambulacral grooves on the actinal surface extend into the interambulacral regions, and are lined by minute tube-feet, while in *Echinanthus* there are isolated "locomotive" pores scattered over many of the interambulacral plates.

In one of these ancient types, from the Cambrian rocks of North America, which Mr Walcott has doubtfully referred to the genus *Æocystites*, there appears to be the exceptional character that the pores are formed by the apposition of corresponding indentations in the edges of contiguous plates (fig. 321, A). In the Ordovician series, and particularly in strata of Llandeilo-Bala age, the remains of Cystideans are sometimes abundant, and the group attains here its maximum. In the Silurian period Cystideans are less abundant, and in the Devonian formation only very few forms (*Tiaracrinus*, *Ateleocystites*, *Strobilocystites*, &c.) are known to occur. Lastly, if *Codaster* be removed to the Blastoids, the group of the Cystideans is chiefly represented in Carboniferous deposits by the aberrant genus *Agelacrinus*.

As regards their *classification*, the Cystideans may be conveniently divided into the three orders of the *Aporitidæ*, *Diploporitidæ*, and *Rhombiferi*, according as the calycine plates are imperforate, are pierced by yoked pairs of pores indiscriminately distributed, or have their pores arranged in "pore-rhombs"; and the characters and principal genera of these three groups may be very briefly glanced at here.

Order 1. Aporitidæ.—In this group are comprised all those Cystideans in which the calyx-plates are destitute of pores. Of the genera of this group *Cryptocrinus* (fig. 325, B) has a globular calyx, composed of comparatively few plates arranged in a tolerably definite manner, there being three basals, succeeded by two cycles of pentagonal plates. The central mouth is, in perfect specimens, covered by a vault of small calcareous plates, and the laterally placed anus is provided with a "valvular pyramid." The stem and arms are unknown, and the genus is confined to the Ordovician rocks. *Malocystites*, from the Ordovician deposits of Canada, possesses an indefinite number of plates in the calyx, and the mouth is excentric, and is surrounded by radiating ambulacral furrows. In *Anomalocystites* (=*Ateleocystites*, Billings) the calyx is also composed of an indefinite number of plates, which are ornamented with transverse striæ. One side of the calyx is convex, while the other is flat or concave, and the summit is provided with delicate armlets or pinnulæ. The species of this genus range from the Ordovician to the Devonian. The most remarkable type of the imperforate Cystideans, however, is that presented by *Agelacrinus* and *Edrioaster*, which have sometimes been regarded as constituting a special family (*Agelacrinidæ*). In the genus *Agelacrinus* (including *Hemicystites*, Hall) the body (fig. 323, A) is in the form of a depressed or convex disc, attached by the whole of its under surface to some foreign body, and therefore devoid of a peduncle. The upper or ventral surface of the disc is covered with numerous

small calcareous plates, which may or may not overlap in an imbricating manner, and exhibits in its centre the opening of the mouth, protected by four "oral" plates. Radiating from the mouth are five curved ambulacral grooves, and in one of the interradial spaces is situated the opening of the anus (*o*), protected by a "pyramid" of calcareous plates. The species of *Agelacrinus* are found in the Ordovician, Silurian, Devonian, and Carboniferous rocks. The genus *Edrioaster* (fig. 323, B), from the Ordovician rocks, agrees in most of its general characters with *Agelacrinus*, but the ambulacral grooves are furnished with a double row of pores on each side.

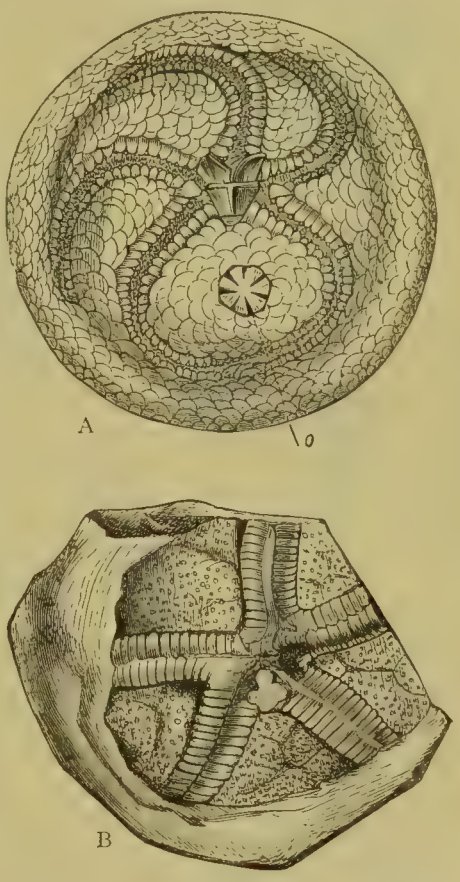


Fig. 323.—A, Upper surface of *Agelacrinus Cincinnatiensis*, enlarged two and a half diameters. Ordovician (after Hall). B, Upper surface of an imperfect specimen of *Edrioaster Bigsbyi*, of the natural size. Ordovician (after Billings). *o*, Anal aperture.

Order 2. Diploporitidæ.—In the Cystideans which are included in this group, the pores are linked or united in pairs, and the individual calyx-plates are pierced by several of such pairs (fig. 321, B). There is, as before pointed out, much probability in the view put forth by Lovén, that the yoked pores of the *Diploporitidæ* served for the passage of tube-feet, and that they thus differ in their real nature from the "pore-rhombs" of the Rhombiferous Cystoids. If this view be correct, the present group is very sharply separated from both the other groups of Cystoids.

As the type of the *Diploporitidæ*, the Ordovician genus *Glyptosphærites* may be taken, in which the globular calyx (fig. 319) is composed of numerous polygonal plates, each of which is perforated by a larger or smaller number of conjugate pores. The mouth is central, and is covered by five oral plates, while converging to it are five branching ambulacral grooves, at the terminations of which are the articular facets to which the armlets or pinnulæ were attached. On one side is the comparatively large opening of the anus, and between the two is a small

aperture which has been usually regarded as a genital pore. The calyx was furnished with a stem composed of thin annular joints. The genus *Sphæronites*, also Ordovician in its range, is allied to the preceding in several points, but there was no stem, and the calyx was adherent by its base to foreign bodies. In the Silurian genus *Gomphocystites* (fig. 324) the calyx has a very peculiar shape, being pyriform, very narrow below, and inflated at its summit. The calyx-plates are in numerous cycles, and have superficial granules, along with yoked pores. The mouth is central, and is surrounded by five spirally wound ambulacral grooves. In *Holocystites*, again, the calyx (fig. 325, F) is long and subcylindrical, and is composed of six or more ranges of hexagonal or polygonal plates. The mouth is central, and the calyx was furnished with a short stem, or was sessile. The genus is found in the Silurian rocks of North America and Europe.

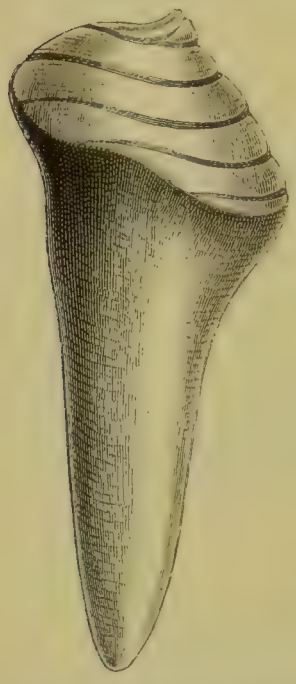


Fig. 324.—Side-view of the cast of the calyx of *Gomphocystites glans*, of the natural size, from the Silurian (Niagara Limestone) of North America. (After Hall.)

Order 3. Rhombiferi.—The Cystideans included in this order are characterised by the possession of pores arranged in rows, corresponding rows in adjoining plates being connected, externally or internally, by grooves or slits which cross the lines of suture between the plates. The pores are thus arranged in groups, which are usually more or less lozenge-shaped, and which are known as "pore-rhombs." The pore-rhombs were probably connected internally with organs similar to those which will be described in dealing with the Blastoids as "hydrospires," and their function seems to have been certainly respiratory.

In one section of this order the plates are indefinite in number, and the pore-rhombs are distributed indifferently over the whole calyx, and are exceedingly numerous. A good example of this section is the well-known Ordovician genus *Echinosphærites* (fig. 325, A), in which the calyx is of large size, globular, and stemless, its base being attached to foreign bodies. The calyx-plates are very numerous, polygonal, with pore-rhombs on every side (fig. 321, C). At the apex is the mouth, and the anus is lateral and is protected by a large "valvular pyramid," while a small ovarian (?) opening is placed between the two. *Caryocystites*, also Ordovician, is nearly

related to *Echinosphærites*, but the calyx is more of an ovoidal form, and the plates are ridged or striated. Allied genera are *Palæocystites* and *Comarocystites*, both from the Ordovician rocks of North America, and the latter remarkable in having a small number of pinnate arms.

In a second group of the *Rhombiferi*, the pore-rhombs are confined to the sides of the calyx, and the upper surface is formed of imperforate plates, while the arrangement of the calycine plates

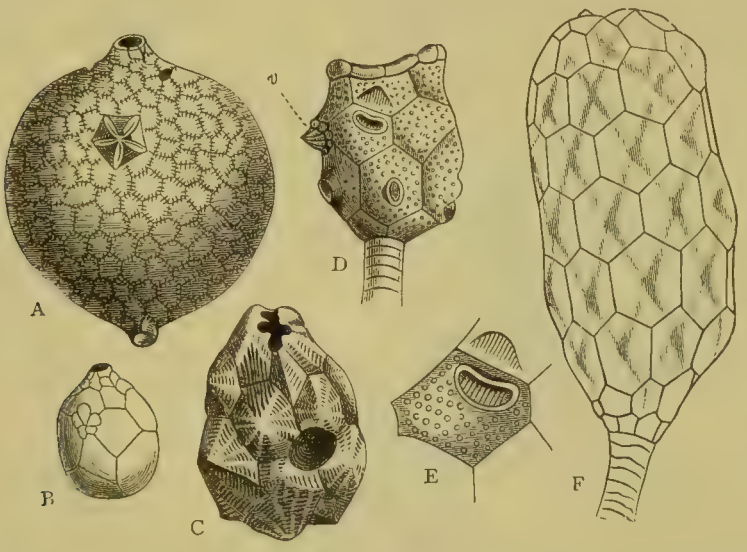


Fig. 325.—A, *Echinosphærites aurantium*; B, *Cryptocrinus lævis*; C, *Echinoencrinus Senkenbergi*; D, *Echinoencrinus* (?) *armatus*; E, One of the "pectinated rhombs" of the last, enlarged; F, *Holocystites cylindricus*. *v*, Valvular anal pyramid. All the specimens are viewed from one side. (A, B, and C are after von Buch; D is after Edward Forbes; and F is after Hall.)

generally is to a greater or less extent radial. A good example of this group is afforded by the genus *Caryocrinus* (fig. 326, A), which is widely distributed in the Silurian rocks of North America. In this genus there is a long and cylindrical column, which carries an ovoid calyx, the upper surface of which exhibits the articular facets to which free-jointed armlets or pinnulæ were attached. The lateral calyx-plates show externally lines of pores radiating from their centres, and an internal examination shows that these pores are connected by canals into pairs, so as to form a series of "rhombs." *Hemicosmites* (fig. 318) is an allied genus, which is found in the Ordovician and Silurian deposits of Europe.

Finally, in a third group of the *Rhombiferi* are included forms in which the calyx-plates are generally more or less definite in number, and more or less clearly arranged in a quinary manner, while the "pore-rhombs" are limited in number, and are often so disposed that

the component halves of each are separated externally by an interval (fig. 322, c). Of the more important genera of this group, *Pleurocystites* is remarkable in having the perisomatic plates on the dorsal side of the calyx large and definitely arranged, while those of the ventral side are numerous and indefinite. The summit of the calyx carries two jointed armlets (fig. 326, B), and there are three "pore-rhombs," or, as these structures were termed by Edward Forbes, "pectinated rhombs." The genus is found in the Ordovician rocks of Canada. In the Ordovician genus *Echinoencrinus* (fig. 325, c) the calyx is composed of four series of plates, there being four basals,

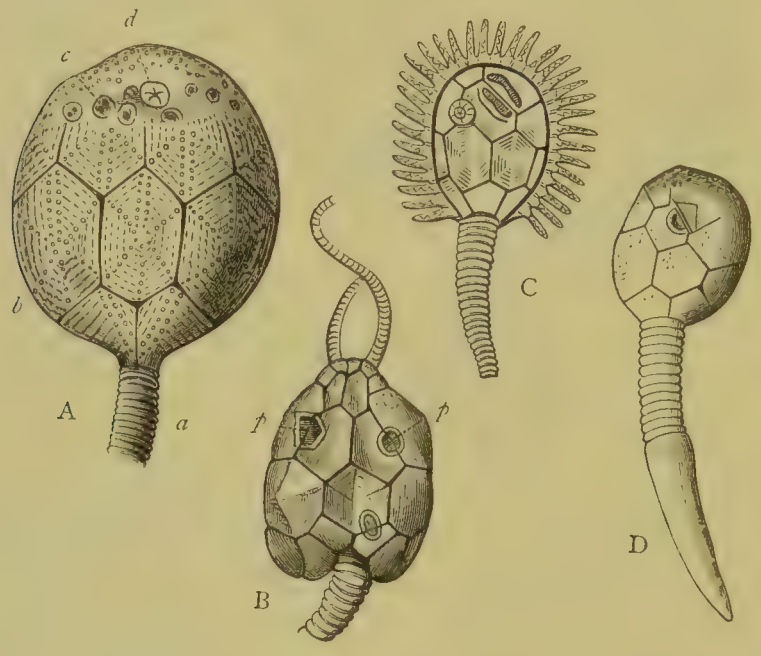


Fig. 326.—A, *Caryocrinus ornatus*: *a*, Column; *b*, Calyx; *c*, Scars where pinnulæ were attached; *d*, Valvular pyramid. B, *Pleurocystites squamosus* (dorsal side): *f f*, Two of the pore-rhombs. C, *Lepadocrinus* (*Pseudocrinus*) *bifasciatus*. D, *Lepadocrinus Gebhardi*.

and five plates in every cycle above this. There are three "pectinated rhombs," and the anal opening is of large size and is placed on one side. The Silurian Cystideans referred to this genus by Edward Forbes under the names of *E. baccatus* and *E. armatus* (fig. 325, D) differ in some important points from the type of *Echinoencrinus*. *Glyptocystites*, of the Ordovician rocks of America and Europe, is allied to the preceding, but possesses numerous "pore-rhombs" (ten to twelve in number), no other genus of this section having more than three or four of these organs. In *Lepadocrinus*—with which Zittel unites *Pseudocrinus* and *Apiocystites*—the calyx is ovoid, more or less quadrangular, with a long stem, which becomes attenuated

below, or ends in an elongated and pointed ossicle (fig. 326, D). The mouth is central, and there are two or four ambulacral grooves, which in well-preserved examples are bordered by short pinnules (fig. 326, C). The anus is excentric, and is furnished with valvular plates, and there are three reniform or triangular pore-rhombs. The genus is principally Silurian. Lastly, in *Callocystites*, as in the preceding genus, the calyx consists of four zones of plates, of which the lowest consists of four basals. The mouth is central, and there are five ambulacral grooves (fig. 320), which are bordered by well-developed pinnules. The anus is excentric, and there are four pectinated rhombs. The species of *Callocystites* are found in the Silurian rocks of North America.

Class III. Blastoidea.

This class includes extinct Echinoderms in which *the body ("calyx") is pyriform, clavate, ovate, or globular, and is attached by a short jointed peduncle, which is in some cases wanting. The calyx exhibits complete radial symmetry, and is enclosed in a covering of suturally united calcareous plates, consisting of basals, radials, and interradials. The upper surface exhibits five ambulacral areas, usually of a more or less petaloid shape, which radiate from the mouth, the latter being superior and central, and being concealed by a covering of small calcareous plates, some of which represent the "orals" of the Crinoids, while the ambulacral grooves are protected by a double row of "covering-plates." Small jointed appendages or "pinnules" are attached, in a single or double row, to the sides of the ambulacral fields, but no true arms are present. "Hydrospires," opening by five or ten apertures round the mouth or by interradial fissures, are present, but are limited to the radial and interradial plates, never extending on to the basals.*

The Blastoids form a peculiar group of Palæozoic Echinoderms, in which the body is generally supported by means of a short peduncle composed of discoidal joints, though in some cases no stem appears to have been present. The calyx is globular, ovoid, clavate, or bell-shaped, and is remarkable for its regular radial symmetry. Underbasals, such as are found in the "dicyclic" Crinoids, are not developed, but the calycine plates consist of a cycle of basals, a row of radials, and a circle of interradial ("deltoid") plates. The basals (fig. 327, A and 328, B) are three in number, two being comparatively large and of equal size, while the third is much smaller. Following the basals is a cycle of five "radials," which are usually of large size, and form the sides of the calyx (figs. 327 and 328, *d*). The radials have been sometimes spoken of as the "forked plates," owing to the fact that each is deeply divided or

incised distally, in such a way that the two arms of the plate enclose the lower end of one of the ambulacral fields. The radials differ from the corresponding plates of the Crinoids in the important fact that they do not form the starting point for a crown of "arms." Placed towards the summit of the calyx, at the angles of junction of the radials, are five triangular, rhomboidal, or pentagonal interradial plates, which have commonly been spoken of as the "deltoids" (fig. 327, A and B, *i*). The cycle of the deltoids is interrupted by the ambulacra, and a considerable portion of their entire area may be hidden from view beneath the adjoining plates

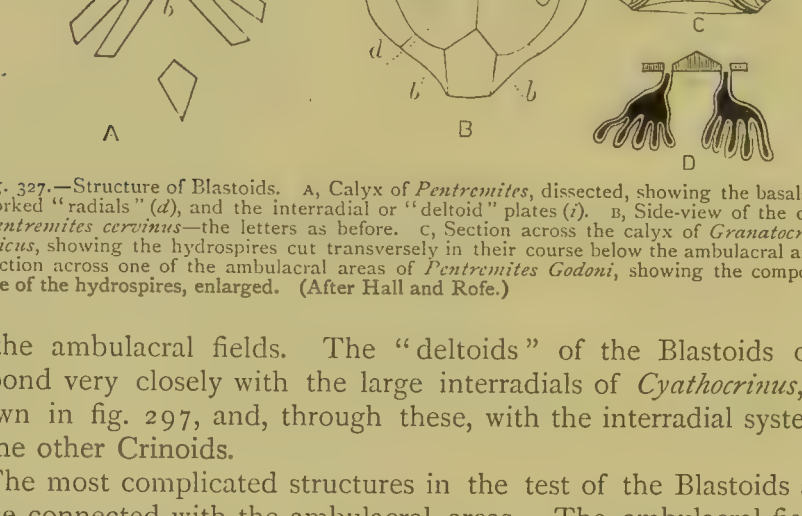


Fig. 327.—Structure of Blastoids. A, Calyx of *Pentremites*, dissected, showing the basals (*b*), the forked "radials" (*d*), and the interradial or "deltoid" plates (*i*). B, Side-view of the calyx of *Pentremites cervinus*—the letters as before. C, Section across the calyx of *Granatocrinus ellipticus*, showing the hydrospires cut transversely in their course below the ambulacral areas. D, Section across one of the ambulacral areas of *Pentremites Godoni*, showing the compound nature of the hydrospires, enlarged. (After Hall and Rofe.)

of the ambulacral fields. The "deltoids" of the Blastoids correspond very closely with the large interradials of *Cyathocrinus*, as shown in fig. 297, and, through these, with the interradial systems of the other Crinoids.

The most complicated structures in the test of the Blastoids are those connected with the ambulacral areas. The ambulacral fields (formerly spoken of as the "pseudambulacra") are always five in number, and pass in a radiating manner from the centre of the summit of the calyx to its margins. It is these which give to the summit of the body its resemblance to a flower-bud (figs. 327, B, and 328, A) upon which the name of the class is founded (Gr. *blastos*, a bud; and *eidos*, form). Though usually broad and petaloid in shape, the ambulacra are sometimes narrow, and their length varies in different types of the class. In a typical Blastoid, such as a species of *Pentremites*, the ambulacra have the following structure. Running down the centre of each of the petaloid ambulacral fields is a well-marked median groove, often with crenulated edges (fig. 329, B, *ag*), which in perfect specimens is roofed over by a double row of small calcareous ossicles or "covering-plates (fig. 329,

A, *c*). This median groove clearly corresponds with the "food-groove" of the arm and disc of a Crinoid, and may therefore be termed the "ambulacral groove." The ambulacral groove is excavated in the middle line of a long pointed plate (fig. 329, B, *l*) which runs down the centre of the ambulacral field and was termed by F. Roemer the "lancet-plate." The two halves of the lancet-plate, in well-preserved specimens, are seen to be crossed by numer-

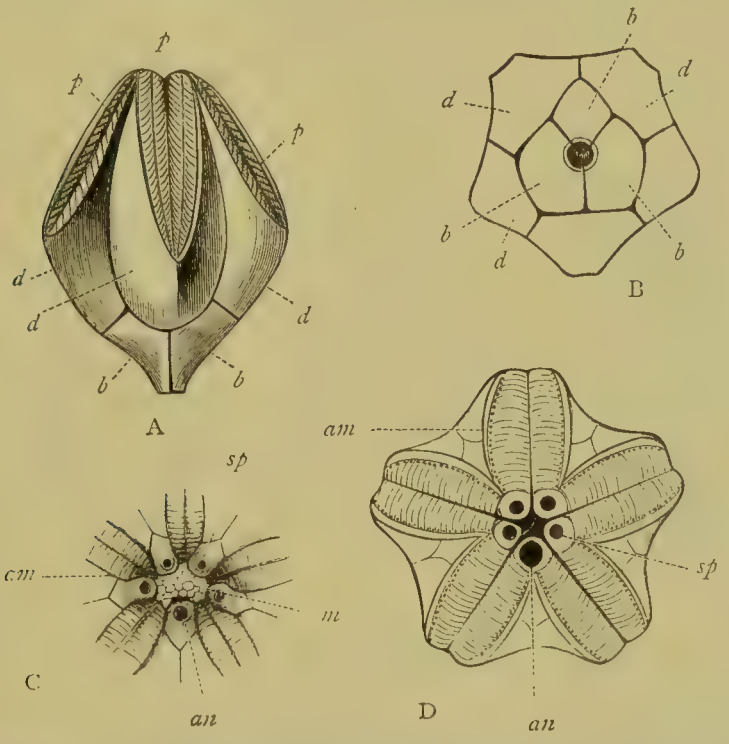


Fig. 328.—A, and B, Side-view and base of *Pentremites pyriformis*: *b b*, Basals; *d d*, Radials; *f f*, Ambulacral fields. C, Summit of *Granatocrinus Norwoodi* (after Meek and Worthen), enlarged, showing the plated membrane covering the mouth (*m*), the spiracles (*sp*), the anus (*an*), and the summits of the ambulacral fields (*am*). D, Summit of *Pentremites sulcatus* (after Ferd. Roemer), showing the mouth denuded of its covering-plates and placed in the centre of the spiracles (*sp*): *an*, Anal opening; *am*, One of the ambulacral fields. From the Carboniferous rocks.

ous transverse grooves, which open centrally into the main ambulacral groove. As the lancet-piece is narrower than the ambulacral field, there exists on each side of the former an interval, separating the sides of the lancet-plate from the forks of the bounding radial on each side. This interval is occupied on each side by a row of small quadrilateral ossicles or "side-plates" (fig. 329, *s*), which complete the ambulacral field superficially. Each ambulacral area is thus traversed from end to end by two lines of suture (fig. 329, B), which separate the median lancet-plate from the side-plates at its edges.

In *Pentremites* and in most other genera of Blastoids, the side-plates are so shaped as to leave along their outer ends a series of apertures or "marginal pores" (fig. 329, *p*), by means of which water is admitted to the "hydrospires." In many cases, however, the marginal pores are not merely spaces between the attenuated outer ends of the side-plates, but they are in part formed by a series of still smaller ossicles, which are known as the "outer side-plates" (the "supplemental pore-plates" of Roemer). In *Pentremites* the side-plates are marginal, and leave the whole upper surface of the lancet-plate exposed to view; but in other cases they encroach upon

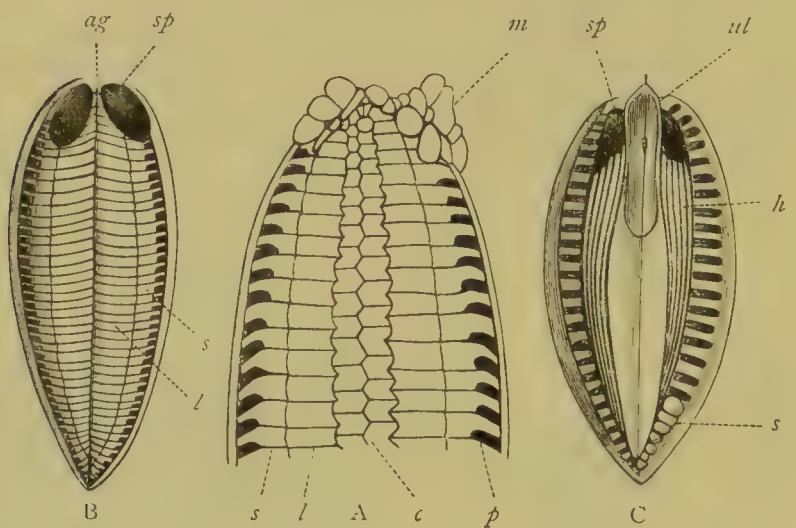


Fig. 329.—A, Upper portion of one of the ambulacra of *Pentremites sulcatus*, enlarged, showing the "covering-plates" (*c*) of the ambulacral groove, passing superiorly into the plated canopy (*m*) which conceals the mouth. B, Ambulacrum of *Pentremites pyriformis*, from which the covering-plates have been removed, showing the ambulacral groove (*ag*), the lancet-plate (*l*), the side-plates (*s*) with their marginal pores, and the spiracles (*sp*) at the upper end. C, Ambulacrum of the same species, from which the lancet-plate and most of the side-plates have been removed, showing the "under lancet-plate" (*ul*), the tops of the hydrospires, (*h*), and the ambulacral opening. (After R. Etheridge, jun., and P. H. Carpenter.)

the lancet-plate, and leave visible little more than the central food-groove.

The lancet-plate is pierced by a canal which lodged the radial water-vessel, and which opens into a circular ambulacral canal surrounding the mouth. The removal of the lancet-plate allows the top of the "hydrospires" to be seen (fig. 329, C, *h*). In the genus *Pentremites*, however, and in some other types, there is situated beneath the lancet-plate, in the middle line of the ambulacral field, an elongated, trough-like plate, which Messrs Etheridge and Carpenter have termed the "under lancet-plate" (fig. 329, *ul*).

True "arms," comparable with the structures so called in the Crinoids, are not developed in the Blastoids. Along the outer edge

of each ambulacral field there was situated, however, a single or double row of slender jointed "pinnules." The sockets for these are placed between each pair of marginal pores, but the delicate pinnules themselves are rarely preserved.

In perfect specimens of the Blastoids, the apex of the ventral surface (fig. 328, C) appears to have been closed by a canopy of small calcareous plates, some of which represent the orals of Crinoids; but in the majority of examples these have been destroyed in the process of fossilisation. In the Blastoids, therefore, as in the Palæocrinoids generally, the mouth was really subtegminal, and was not visible externally in the natural condition. When the covering-plates, however, have been lost, the mouth is seen as a central aperture placed at the point of convergence of the ambulacral fields (fig. 328, D). The vault of plates concealing the mouth passes laterally without a break into the "covering-plates" of the ambulacral grooves. The anus is excentric, and pierces one of the interradials ("deltoid" plates).

The most remarkable organs in the Blastoids are the respiratory tubes or "hydrospires," which are probably always present in one form or another, though they have not been universally detected. In *Pentremites* (fig. 330) the hydrospires lie underneath the lateral portions of the ambulacral fields, one on each side of each ambulacrum, so that there are ten of these organs in all. When the lancet-plate is removed from an ambulacrum in this genus, the outer sides of the hydrospires are seen on each side (fig. 329, C, *h*), with the "under lancet-plate" in the centre. Each hydrospire consists of a flattened lamellar tube, with thin calcareous walls, more or less extensively folded, and terminating internally by closed and somewhat dilated ends, the reduplications of the tube being placed lengthways beneath the ambulacrum. Water is admitted into the hydrospires by slits on their outer faces in direct connection with the rows of "marginal pores" between the overlying "side-plates" of the ambulacrum (fig. 330, *p p*). At their upper ends the hydrospires are placed in further communication with the exterior by a ring of five or ten openings surrounding the peristome. These apertures (formerly called "ovarian openings") are usually spoken of as the "spiracles" (fig. 328, C), and they probably served for the escape of water from the hydrospires.

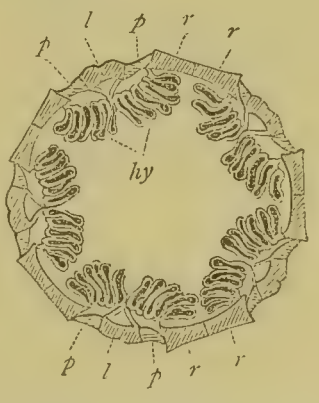


Fig. 330.—Cross-section of the calyx of *Pentremites sulcatus*, from the Carboniferous rocks of Illinois, somewhat enlarged, showing the transversely divided "hydrospires" (*hy*); *r r*, Radial plates; *l*, Lancet-plate; *p p*, Side-plates. (After Zittel.)

The general arrangement of the hydrospires in the majority of the Blastoids is essentially similar to that which obtains in *Pentremites*, as above briefly described; but there are some remarkable departures from this type. Thus in *Codaster* (=*Codonaster*) there are only eight hydrospires, and these open externally by slits separated by intervening ridges, which occupy four of the five interradial areas on the ventral surface of the body, and which have a direction parallel with that of the ambulacra (fig. 331, A). In *Phænoschisma* the arrangement is the same, but the

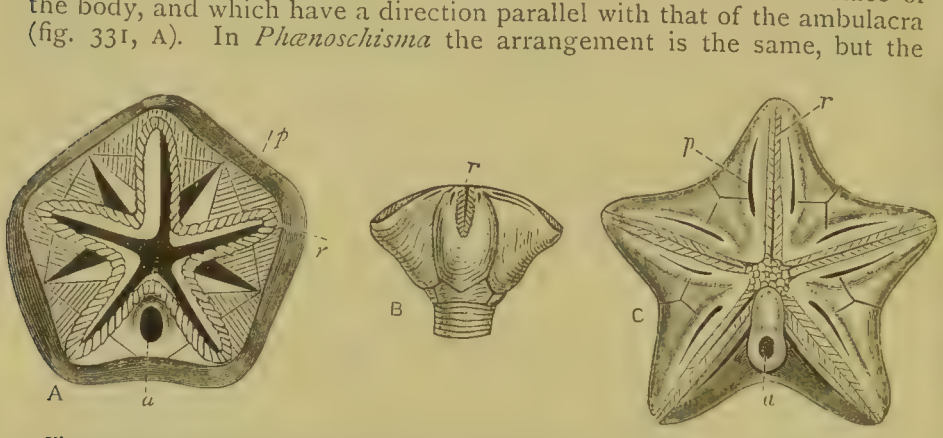


Fig. 331.—A, Upper surface of the calyx of *Codaster trilobatus*, var. *acutus*, from the Carboniferous Limestone, enlarged, showing the numerous hydrospire-slits (*p*) in all the interradii except the anal one. (After M'Coy.) B, Side-view of the calyx of *Orophocrinus* (*Codonites*) *stelliformis*, from the Carboniferous Limestone of North America, of the natural size. C, Upper surface of the calyx of the same (after Meek and Worthen), enlarged. *a*, Anal aperture; *r*, Ambulacra; *p*, in fig. C, Hydrospire-clefts or "spiracles."

hydrospire-slits occupy the anal as well as the other four interradii. Lastly, in the genus *Orophocrinus* (fig. 331, C) the "spiracles" or external openings of the hydrospires are in the form of ten clefts, of variable length, which extend along the sides of the ambulacra.

There can be little doubt that the "hydrospires" of the Blastoids, like the less highly developed structures of the same kind in the Cystoids, are essentially respiratory in function. They present in many respects a remarkable resemblance to the folded genital "bursæ" of the Ophiuroids, as regards both their structure and their mode of termination on the surface of the body. It is therefore probable that the hydrospires, like the "bursæ" of the Brittle-stars, were connected with the discharge of the reproductive elements into the external medium.

As regards the *distribution in time* of the Blastoids, no member of the order has been as yet certainly detected in the Ordovician rocks. In the Silurian rocks of North America a few forms have been found, and in the Devonian deposits both of the New and Old World various genera are represented, such as *Pentremitidea*, *Eleutherocrinus*, *Codaster*, and *Elæacrinus*. It is in the Carboniferous rocks, however, that the Blastoids attain their maximum development, the type-genus *Pentremites* (fig. 332, *a* and *b*)—sometimes written *Pentatremites* or *Pentatrematites*—appearing here for the

first time. The other genera most largely represented in the Carboniferous rocks are *Granatocrinus*, *Schizoblastus* (fig. 332, *c*), *Codaster* (fig. 331, A), *Orophocrinus* (fig. 331, B), and *Mesoblastus*. Above the horizon of the Carboniferous Limestone no remains of Blastoids have been as yet discovered.

As regards their *classification*, the Blastoids are divided by Mr Etheridge, jun., and Dr P. H. Carpenter, into the two primary groups or orders of the *Regulares* and *Irregulares*, the former including pedunculate types with a symmetrical base and having equal and similar ambulacra, while the latter comprises sessile forms

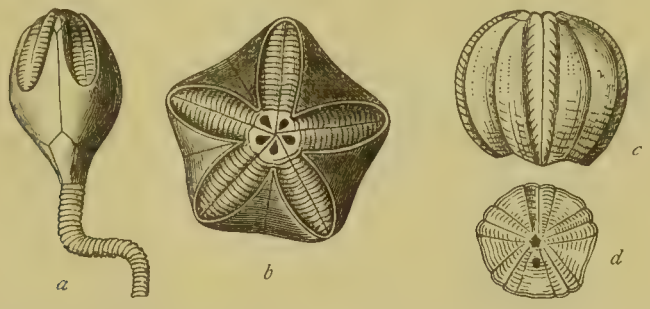


Fig. 332.—*a*, *Pentremites pyriformis*, viewed sideways, showing a portion of the column; *b*, Summit of the calyx of *Pentremites cervinus*, showing the ambulacral areas and the apical apertures; *c*, Side-view of *Schizoblastus melonoides*; *d*, Summit of *Schizoblastus neglectus*. (Figs. *a* and *b* are of the natural size; *c* and *d* are slightly enlarged.) (After Hall, and Meek and Worthen.)

in which the base is usually unsymmetrical, and one ambulacrum and the corresponding radial are different from their fellows. The following table exhibits the families adopted by the authorities just named, with the genera included in each :—

Order I. Regulares.

Family 1. *Pentremitidæ*.—Base usually convex and often much elongated. Spiracles five, but sometimes more or less completely divided by a median septum. Their distal boundary formed by side-plates. Hydrospires concentrated at the lowest part of the radial sinus. The genera *Pentremites* (fig. 328), *Pentremitidea*, and *Mesoblastus* are included in this family.

Family 2. *Troostoblastidæ*.—Ambulacra very narrow, and descending sharply outwards from the much-restricted peristome. Deltoids usually limited to the summit and rarely visible externally. Lancet-plate entirely covered by the side-plates. Spiracles generally double, appearing as linear slits at the sides of the deltoid ridge, but not bounded distally by side-plates. The genera *Troostocrinus*, *Metablastus*, and *Tricœlocrinus* belong here.

Family 3. *Nucleoblastidæ*.—Calyx usually globular or ovoidal, with flattened or concave base and linear ambulacra. Spiracles distinctly double, and chiefly formed by the apposition of notches in the lancet-

plate and deltoids. This family includes *Elæacrinus* (with an anal plate); and *Schizoblastus* (fig. 332, *c* and *d*), *Cryptoblastus*, and *Acentotremites* (without an anal plate).

Family 4. *Granatoblastidæ*.—Calyx globular or ovoidal, with a flattened or concave base and linear ambulacra. Spiracles five, piercing the deltoids; or ten, grooving their lateral edges. This family includes the genera *Granatocrinus* and *Heteroblastus*.

Family 5. *Codasteridæ*.—Base usually well developed and sometimes very long. Some or all of the hydrospire-slits pierce the calyx-plates on the sides of the radial sinus, restricted portions of which may remain open as the spiracles. This family includes the genera *Codaster* (fig. 331, A), *Phænoschisma*, *Orophocrinus* (fig. 331, B and C), and *Cryptoschisma*.

Order II. Irregulares.

Family 6. *Astrocrinidæ*.—This family includes certain singular unstalked and unsymmetrical Blastoids, in which one ambulacrum and one radial are different from the rest. In *Astrocrinus* and *Eleutherocrinus* the basals are unsymmetrical, and the azygos radial is small and without definite limbs, its ambulacrum being short, wide, and horizontal. On the other hand, in *Pentephyllum* the basals are symmetrical, and the odd ambulacrum is linear.

LITERATURE OF ECHINODERMATA.

General.

1. "Ueber den Bau der Echinodermen." 'Abhandlungen der Berlin Akad.' 1853. Joh. Müller.
2. "Morphologische Studien an Echinodermen." H. Ludwig. Leipzig, 1877-82.
3. "Histoire naturelle des Zoophytes Échinodermes." Dujardin and Hupé. Paris, 1862.
4. "Monographie d'Échinodermes vivants et fossiles." Louis Agassiz. 1838-41.
5. "Handbuch der Palæontologie," Abth. I., Lief. 3. Zittel. 1879.
6. "Beiträge zur Histologie der Echinodermen," I.-IV. Hamann. 1884-89.
7. "Die Stämme des Thierreichs." Bd. I. Neumayr.
8. "Bronn's Klassen und Ordnungen des Thierreichs" (Echinoderms). 2d Ed. 1889. Ludwig.
9. "Notes on Echinoderm Morphology," I.-XI. 'Quart. Journ. Micro. Sci.' 1878-87. P. H. Carpenter.

Echinoidea.

10. "Catalogue raisonné des familles, des genres, et des espèces de la classe des Échinodermes." Louis Agassiz and Desor. 1847.
11. "Revision of the Echini." Alexander Agassiz. 'Memoirs of the Museum of Comparative Zoology at Harvard,' vol. iii. 1872-74.
12. "Monograph of the British Fossil Echinodermata." Thomas Wright. 'Palæontographical Society.'
13. "Études sur les Échinoïdées." Svenska Vetensk. Handl.' Bd. xi. 1874. Lovén.

14. "Pourtalesia." Ibid. Bd. xix. Lovén. 1883.
15. "Report on the Echinoidea." 'Challenger Reports,' vol. iii. 1881. Alexander Agassiz.
16. "Report on the 'Blake' Echini." Alexander Agassiz. 1883.
17. "Synopsis des Échinides fossiles." Desor. 1855-59.
18. "Paléontologie française." Terrains crétacés. Échinides irreguliers, vol. vi. 1856-57. D'Orbigny.
19. "Paléontologie française" (a continuation of the preceding). Cotteau.
20. "Monograph of the Echinodermata of the British Tertiaries." 'Palæontographical Society.' Edward Forbes.
21. "Petrefaktenkunde Deutschlands." Bd. iii. Echiniden. Quenstedt. 1872-75.
22. "Petrefacta Germaniæ." Bd. i. Goldfuss. 1826-33.
23. "Palæozoic Fossils." M'Coy. 1851. (*Perischoechinidæ.*) Also "Carboniferous Fossils of Ireland." 1844.
24. "Echinothuridæ and Perischoechinidæ." R. Etheridge, jun. 'Quart. Journ. Geol. Soc.,' vol. xxx. pp. 307-316. 1874.
25. "Échinologie helvetique." De Loriol. 1868-1875.
26. "Die Echiniden der vicentinischen und veronesischen Tertiärablagerungen." 'Palæontographica.' Dames. 1877.

Asteroidea and Ophiuroidea.

27. "System der Asteriden." Müller and Troschel. 1843.
28. "Ophiuridæ and Astrophytidæ." Theodore Lyman. 'Illustrated Catalogue of the Museum of Comparative Zoology at Harvard.' 1865.
29. "Additamenta ad historiam Ophiuridarum." Lütken. 1859.
30. "Report on the Asteroidea." 'Challenger Reports,' vol. xxx. 1889. Sladen.
31. "North American Star-fishes." A. Agassiz. 1877.
32. "Report on the Ophiuroidea." 'Report on the Scientific Results of the Voyage of H.M.S. Challenger,' vol. v. Lyman. 1882.
33. "Revision de la Collection du Musée d'histoire naturelle de Paris." 'Arch. Zool. Expérim. et générale,' vols. iv. and v. 1875, 1876. Perrier.
34. "Anatomie comparée du squelette des Stellérides." Ibid., vol. vii. 1878. Viguier.
35. "British Fossil Echinodermata." 'The Asteroidea.' Thomas Wright. 'Palæontographical Society.' 1862 and 1866.
36. "British Fossil Asteriadæ." 'Mem. Geol. Survey,' vol. ii., Part ii., and Decade iii. Edward Forbes. 1848 and 1850.
37. "New Palæozoic Star-fishes." Salter. 'Ann. and Mag. Nat. Hist.,' ser. 1, vol. xx. 1857.
38. "Asteriadæ of the Lower Silurian Rocks of Canada." Billings. 'Geol. Surv. of Canada," Decade iii. 1858.
39. "The Genus Palæaster," &c. James Hall. 'Twentieth Ann. Rep. on the State Cabinet.' 1868.
40. "Neue Asteriden aus devonischem Dachschiefer von Bundenbach bei Birkenfeld." 'Palæontographica,' vol. ix. 1862. Ferd. Roemer.
41. "Ueber einige Asteroiden der rheinischen Grauwacke." 'Sitzungsberichte d. Wien Akad.' Bd. lxiii. 1871. Simonowitsch.
42. "Beitrag zur Kenntniss Palæozoischer See-Sterne." 'Palæontographica.' Bd. xxxii. 1886. Stürtz.

Holothuroidea.

43. "Die Seewalzen, eine systematische Monographie." Lampert. 1885.
44. "Monographie de l'étage Bathonien de la Moselle." Terquem and Jourdy.
45. "On the presence of scattered Skeletal Remains of Holothuroidea in the Carboniferous Limestone Series of Scotland." 'Proc. Royal Physical Soc. of Edinburgh.' 1880-81. R. Etheridge, jun.
46. "Note sur les Holothuridées du Calcaire Grossier." Schlumberger.

Crinoidea.

47. "A Natural History of the Crinoidea," &c. J. S. Miller. 1821.
48. "Memoir on the Pentacrinus Europæus." J. V. Thomson. 1827.
49. "Ueber den Pentacrinus caput-Medusæ." J. Müller. 1843.
50. "Development of Comatula." Sir Wyville Thomson. 'Phil. Trans.' 1865.
51. "On the Structure, Physiology, and Development of Antedon rosaceus." Dr W. B. Carpenter. 'Proc. Roy. Soc.' 1876.
52. "Anatomy, Physiology, and Development of Comatula." Dr W. B. Carpenter. 'Phil. Trans.' 1866.
53. "On the Oral and Apical Systems of Echinoderms." 'Quart. Journ. Micro. Sci.,' vols. xviii., xix. P. H. Carpenter.
54. "Report on the Crinoidea." 'Report on the Scientific Results of the Voyage of H.M.S. Challenger,' vol. xi. 1884. P. H. Carpenter.
55. "Report on the Crinoidea." Part II. The Comatulæ. 'Rep. on the Scientific Results of the Voyage of H.M.S. Challenger,' vol. xxvi. 1888. P. H. Carpenter.
56. "The Early Stages in the Development of Antedon rosaceus." H. Bury. 1888.
57. "Revision of the Palæocrinoidea." Wachsmuth and Springer. Philadelphia. 1879-86.
58. "Monographie der Echinodermen der Eifler Kalk." Schultze. 'Denkschr. derk. k. Akad. der Wiss. Wien.' 1867.
59. "Recherches sur les Crinoides du terrain carbonifère de la Belgique." De Koninck and Le Hon. 1854.
60. "The Crinoidea of the Lower Silurian Rocks of Canada." E. Billings. 'Figures and Descriptions of Canadian Organic Remains.' Decade iv. 1859.
61. "Palæontology of Illinois," vol. v. Meek and Worthen. 1873. (Carboniferous Crinoids and Blastoids.)
62. "Palæontology of Ohio," vols. i. and ii. Meek. 1873 and 1875. (Descriptions of Silurian and Carboniferous Crinoids.)
63. "Handbuch der Palæontologie," Bd. i., Lief. 3. 1879. Zittel.
64. "Discovery of the ventral structure of *Taxocrinus* and *Haplocrinus*, and consequent modifications in the Classification of the Crinoidea." Wachsmuth and Springer. 1889.

Cystoidea.

65. "On the Cystidea of the Lower Silurian Rocks of Canada." E. Billings. 'Figures and Descriptions of Canadian Organic Remains.' Decade iii. 1858.
66. "Notes on the Structure of the Crinoidea, Cystidea, and Blastoidea." E. Billings. 'Palæozoic Fossils,' vol. ii. 1874.

67. "Ueber Cystideen." Von Buch. 1845. (Translated in 'Quart. Journ. Geol. Soc. Lond.' 1845.)
68. "Russische Sphæroniten." Von Volborth. 1846.
69. "British Fossil Cystideæ." Edward Forbes. 'Mem. Geol. Survey,' vol. ii. part ii. 1848.
70. "Twentieth Report on the State Cabinet." James Hall. 1868. (Silurian Cystideans.)
71. "Système Silurien du Centre de la Bohême." (Cystideans.) Barrande (W. Waagen). 1888.

BLASTOIDEA.

72. "Monographie der fossilen Crinoideen-Familie der Blastoideen." Ferdinand Roemer. 1851.
73. "Catalogue of the Blastoidea in the Geological Department of the British Museum." 1886. R. Etheridge, jun., and P. H. Carpenter.
74. "Notes on Echinodermata." Rofe. 'Geol. Mag.,' Dec. i., vol. ii. 1865.

CHAPTER XXVII.

SUB-KINGDOM V.—ANNULOSA.

Characters and Divisions of Annulosa—The Scolecida and Anarthropoda.

Sub-kingdom Annulosa.—The Annulose animals are characterised by the possession of *a body which is usually more or less elongated, and is always bilaterally symmetrical instead of being radially disposed. Very commonly the body is divided into similar* (*homonomous*) *segments, which may be definite or indefinite, and are arranged along an antero-posterior axis. Lateral appendages may be absent or present, and when present, are symmetrically disposed. A nervous system is present, and consists of one or two ganglia placed in the anterior part of the body, or of a ventrally-placed, double gangliated chain.*

The sub-kingdom of the *Annulosa* may be divided into the three primary sections of the *Scolecida*, the *Anarthropoda*, and the *Arthropoda*, of which the two former are often separated to form a single great division of the animal kingdom under the name of *Vermes*. The division of the *Arthropoda* comprises the Crustaceans, the Arachnids, the Myriopods, and the Insects, the great majority of which are provided with a resisting exoskeleton, which is typically composed of chitine, but is often more or less largely calcified. Hence, the record of this division in past time is a comparatively complete one, its earliest representatives appearing in deposits of Cambrian age. The division of the *Anarthropoda* comprises the typical "Worms" (Leeches, Earthworms, Sea-worms, &c.), in which exoskeletal structures are often completely wanting, or are only partially developed. Hence the palæontological history of these animals is a necessarily very imperfect one. We have, however, unquestionable proofs of the existence of Sea-worms in rocks as ancient as the Ordovician, at any rate; and, if we may judge from the evidence of "tracks" or "burrows," the lower Cambrian

(and possibly even the Laurentian) deposits contain the remains of animals belonging to this division. Finally, the division of the *Scolecida* comprises the various "Worms" which from their commonly parasitic habit are generally known as the *Entozoa*, together with the group of the Wheel-animalcules or *Rotifera*. To say nothing of the microscopic dimensions of the Rotifers and many of the *Entozoa*, none of the Scolecids are provided with hard structures, which, under ordinary conditions, could possibly be preserved in the fossil state. It would, therefore, be no matter of surprise to find that we have absolutely no record of the existence of these animals in past time. There are, however, a few remains which have been referred to the *Entozoa*, and which may be noted here. The most satisfactory of these is a worm which was found by von Heyden in the abdomen of a fossil Beetle from the Miocene Brown Coal of Germany, and which has been referred to the Hairworms (*Gordiacea*) under the name of *Mermis antiqua*. The same genus has been detected in amber, along with minute filamentous worms which have been referred to the *Nematoda*, and have been placed under the genera *Anguillula* and *Enchytræus*. These are the sole remains of Scolecids which have hitherto been detected, and it is therefore unnecessary here to deal further with this division of the *Annulosa*.

Anarthropoda.

The animals included in this section are usually spoken of as "Worms," and constitute the highest division of the "*Vermes*," as this name is now understood. Under this head are placed the Spoon-worms (*Gephyrea*), the Arrow-worms (*Chætognatha*), and the Ringed Worms (*Annelida*), together with the small and aberrant group of the *Myzostomida*. The division is characterised generally by the usually elongated, vermiform body, which is, typically, composed of numerous, clearly recognisable segments. The segments are in general nearly similar: and when lateral locomotive appendages are developed, these are not composed of successive joints, and are not articulated to the body.

Of the four groups included under the head of *Anarthropoda*, the Annelides are comparatively well represented as fossils, commencing in the Cambrian period. On the other hand, the *Chætognatha* are wholly unknown in the fossil condition; as also are the Gephyreans, unless Ehlers be correct in referring to this group certain obscure remains from the Lithographic Slate (Jurassic) of Germany, for which he proposed the name of *Epitrachys*. The *Myzostomida*, however, have been certainly recognised in the fossil condition, though their geological history is still imperfectly known. *Myzostoma*, the type-genus of this curious and abnormal group,

comprises small, symmetrical, unsegmented animals, with a discoidal body furnished below with five pairs of unjointed feet terminated by hooks, which form cysts, somewhat like plant-galls, upon the calyx, arms, or pinnules of *Comatulæ* and other Crinoids. In various fossil Crinoids the arms or pinnules have been found to be distorted by the cysts of some form belonging to the *Myzostomida*, and further investigation will probably show that this group is really one of great antiquity.

Annelida.

The class of the *Annelida* comprises the so-called Ringed Worms, including the Leeches (*Hirudinea*), the Earthworms and their allies (*Oligochæta*), and the Sea-worms (*Polychæta*). The body in the Annelides is always elongated, and is composed of numerous segments, all the segments, except those at the anterior and posterior extremities of the body, being in general similar to one another. In the Leeches, the segments carry no lateral appendages, and locomotion is effected by means of suctorial discs. In the Oligochætous worms, the segments are provided with locomotive appendages in the form of horny setæ, embedded basally in the integument. Lastly, in the *Polychæta* the segments carry, as a rule, tufts of horny bristles attached to unjointed lateral protuberances or "foot-tubercles" (parapodia).

As regards their *distribution in time*, the *Oligochæta* are wholly unknown as fossils, and no reliable traces of the past existence of the *Hirudinea* have hitherto been discovered; though some problematical fossils from the Lithographic Slate (Jurassic) of Germany have been regarded as the remains of Leeches. The order of the *Polychæta*, on the other hand, comprises worms which are marine in habit and are at the present day very widely distributed, so that we should expect to find ample evidence of their former existence. As the integument of the Polychætous worms is more or less soft, and as the only hard structures developed within the tissues are the horny jaws and the locomotive bristles, it can only be under exceptionally favourable circumstances—as, for example, in the fine-grained Jurassic lithographic slates of Germany—that the actual *body* of these animals can have been preserved in the fossil condition. Many of the *Polychæta*, however, protect themselves by an investing tube which may be composed of lime, or of sand or other adventitious particles cemented together; and the cases of these "Tubicolous" worms are often preserved. The free-swimming or "Errant" *Polychæta*, again, have left evidence of their past existence in their fossilised jaws, as well as by less unequivocal remains in the form of filled-up burrows or meandering

trails upon the soft sand or mud of the sea-bottom. In this way we know that the Polychætous Annelides commenced their existence at least as early as the Cambrian, while obscure traces of their presence have even been detected in the Laurentian period. Owing to their comparatively frequent occurrence as fossils, it is necessary to study this group of Worms in greater detail.

POLYCHÆTA.

SUB-ORDER I. TUBICOLA.—The Worms included in this sub-order are distinguished by the fact that they inhabit variously formed tubes, to which they are not organically connected, and in which they can move freely by means of their setigerous foot-tubercles. Owing to their possession of an investing tube, branchiæ are only developed in the anterior region of the body (fig. 333), this being the only part which is ordinarily exposed to the action of the sea-water; hence the *Tubicola* are sometimes called the "cephalobranchiate" Annelides.

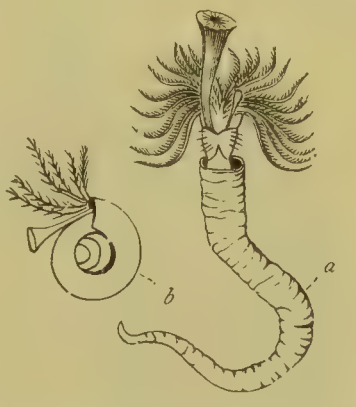


Fig. 333.—Tubicola. *a*, *Serpula contortuplicata*, showing the branchiæ and operculum; *b*, *Spirorbis communis*.

The protecting tube of the Tubicolous Annelides may be composed of carbonate of lime (*Serpula*), of grains of sand (*Sabellaria*), or of sand, pieces of shell, and other adventitious particles cemented together by a glutinous secretion from the body (*Terebella*); or it may be simply membranaceous or leathery (*Sabella*). Sometimes the tube is free and non-adherent (*Pectinaria*); more commonly it is attached to some submarine object by its apex or by one side (*Serpula* and *Spirorbis*). Sometimes the tube is single (*Spirorbis*, generally); sometimes the animal is social, and the tubes are clustered together in larger or smaller masses (*Sabellaria*).

When the tube is calcareous, it presents certain resemblances to the shells of some of the Molluscs, such as *Vermetus* and *Dentalium*. In the living state it is easy to make a distinction between these, for the Tubicolar Annelides are in no way organically attached to their tubes, whereas the Molluscs are always attached to their shell by proper muscles. In the fossil condition, however, it may be very difficult to refer a given calcareous tube to its proper place. As a general rule, however, the calcareous tubes of Annelides, such as *Serpula*, are less regular and symmetrical than those

of *Vermetus*, whilst the latter are partitioned by shelly septa, which do not exist in the former. Again, the tube of *Dentalium* is open at both ends, whereas it is closed at one extremity in the *Serpulæ*. In the Annelidous genus *Ditrupa*, however, the tube is open at both ends, so that this distinction is one not universally applicable.

Tubicolar Annelides are certainly known from the Ordovician rocks upwards, almost every great period having representatives of the order, though many of the fossils referred to this group are of a more or less problematical nature. The genus *Spirorbis* has survived from the Silurian period to the present day; and forms apparently not separable from the existing genus *Serpula* are known in deposits at any rate as old as the Carboniferous.

Of the fossil Tubicolar Annelides which are likewise known by still existing types, and the true relations of which are therefore beyond dispute, the three chief genera are *Serpula* (including *Vermilia* and *Filograna*), *Spirorbis*, and *Ditrupa*. In the genus *Serpula* (fig. 334), there is a long shelly tube, usually more or less tortuous, sometimes solitary, sometimes aggregated, which is fixed to some foreign body by a smaller or larger portion of its surface. The genera *Vermilia* and *Filograna* are principally distinguishable from *Serpula* proper by characters belonging to the animal and not to the tube which it inhabits. It is doubtful, therefore, if these three types can be separated in the fossil condition from one another; though it has been adduced as a distinctive character of *Vermilia* that the mouth of the tube often possesses from one to three tooth-like projections.

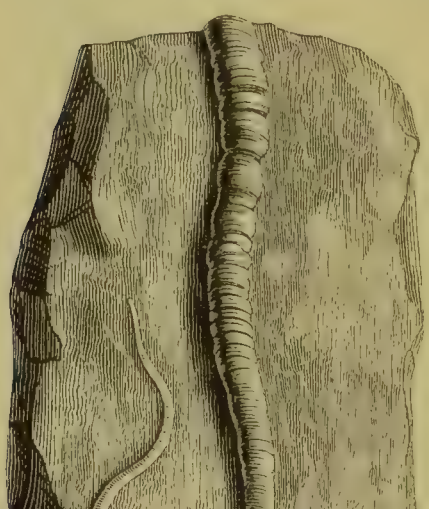


Fig. 334.—*Serpula flagellum*. Oxford Clay. (Jurassic.)

As regards its microscopic structure, the tube of *Serpula* appears to be mainly composed of delicate concentric laminæ of carbonate of lime, with a considerable proportion of animal matter. Some of the layers, and particularly those near the exterior, may be of considerable thickness, and may exhibit a peculiar tubulated structure, being traversed by minute branching canals, the direction of which is at right angles to the long axis of the tube itself (fig. 335, A). In other cases, the

tube is composed of numerous concentric laminæ separated by intervening rows of tolerably large-sized vesicles (fig. 335, B), while in other forms the laminated tissue preponderates and the vesicular tissue is imperfectly developed and is only present in parts of the tube.

As regards the geological range of *Serpula*, the earliest unequivocal types are found in the Carboniferous rocks,[1] but the genus has been asserted to occur in still older deposits. In the Trias and Lower Jurassic rocks *Serpulæ* are not infrequent, but are usually solitary in habit; whereas social types of the genus are not uncommon in the later Jurassic deposits, and entire beds of limestone in the Lower Cretaceous rocks are sometimes made up of the tubes of

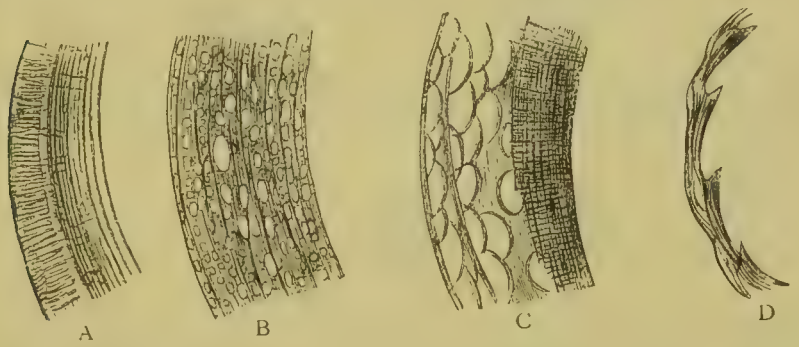


Fig. 335.—Microscopic structure of the tube of some Tubicolar Annelides. A, Cross-section of the tube of *Serpula* sp. (Recent), showing laminated and tubulated calcareous tissue; B, Cross-section of the tube of a Tertiary species of *Serpula*, showing laminated and vesicular tissue; C, Cross-section of the tube of *Cornulites* sp. (Silurian), showing an internal layer of laminated and tubulated tissue, with an outer layer of a vesicular structure; D, Oblique section of a tube of *Conchicolites gregarius* (Ordovician). The figures show only parts of the sections, and are all enlarged. (Original.)

these Annelides. Numerous forms likewise occur in the Tertiary rocks.

In the genus *Spirorbis* (figs. 336-338), the tube is calcareous, and is coiled into a flat spiral, one side of which is cemented to some foreign body. The spiral may be either right-handed ("dextral") or left-handed ("sinistral"), and the last volution is usually more or less elevated, and is often extended into a free bent tube of no great length. Internally the tube is usually open throughout, but in some forms it is divided into chambers by a few calcareous partitions. The tube is usually adorned externally with concentric striæ or annulations, sometimes with tubercles or spines; and all the known forms are of small size. In some species the tube is constantly solitary, but in other cases great numbers are found together. The

[1] The *Serpula parallela*, M'Coy, of the Carboniferous rocks, as previously shown, is really the siliceous "rope" of one of the Hexactinellid Sponges (*Hyalostelia*).

name *Microconchus* has been proposed for forms of *Spirorbis*, which are not simply cemented by the under surface to some foreign substance, but which make a depression or groove in the body to which the tube is attached. The living species of *Spirorbis* are all marine, but some of the extinct forms of the Carboniferous period are commonly found attached to the stems and leaves of undoubted terrestrial plants, a fact which would seem to show that some of these ancient types were able to exist in brackish, or, possibly, even in fresh water.

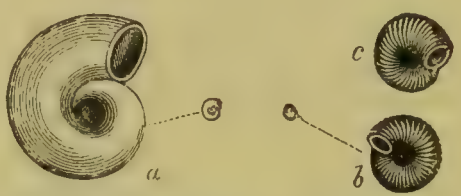


Fig. 336.—*a*, *Spirorbis omphalodes*, natural size and enlarged—Devonian, Europe and America; *b*, *Spirorbis Arkonensis*, of the natural size and enlarged; *c*, The same, with the tube twisted in the reverse direction—Devonian, America. (Original.)



Fig. 337.—*a*, *b*, *Spirorbis laxus*, enlarged—Silurian, America; *c*, *Spirorbis spinuliferus*, of the natural size and enlarged—Devonian, Canada. (After Hall and the Author.)

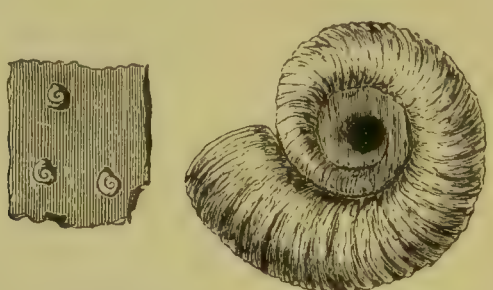


Fig. 338.—*Spirorbis* (*Microconchus*) *carbonarius*, natural size, attached to a fossil plant, and magnified—Carboniferous. (After Dawson.)

The earliest known species of *Spirorbis* occur in the Ordovician rocks, and the genus is abundantly represented in the Silurian, Devonian, and Carboniferous rocks, the tubes often occurring in great numbers attached to the exterior of shells or corals. The *Spirorbis helicteres* of the Carboniferous rocks sometimes occurs in the Carboniferous rocks of Scotland in quantities sufficient to make up bands of limestone of some thickness. Other species have been described from the Permian rocks, and the genus continues to be well represented in both Mesozoic and Tertiary deposits, while liv-

ing forms, apparently little different from the fossil ones, abound in recent seas.

In the genus *Ditrupa*, the tube is free and unattached, open at both ends, and calcareous in composition, its general aspect being very similar to that of the shell of a *Dentalium*. The genus appears to have existed in Carboniferous times, but it is not found in any abundance till the Tertiary period is reached. Species of this genus are abundant in the London Clay (Eocene) and in the Red Crag (Pliocene).

In the Palæozoic rocks there occur the remains of various organisms which have been commonly referred to the Tubicolous Annelides, but which differ more or less extensively in structure and character from any existing types, their precise nature being thus rendered more or less doubtful. Some of the more important of these may be briefly considered here. Among the most problematical of these are the fossils for which the names of *Serpulites* and *Trachyderma* have been proposed. Under the head of *Serpulites* are included smooth, arcuate, semi-calcareous, glossy, apparently unattached, tubular fossils, which sometimes reach a length of a foot, with a diameter of an inch. In the most typical forms of *Serpulites* the tube exhibits two small longitudinal ridges or tubular ribs, placed respectively along the convex and concave faces of the fossil; but these thickened borders do not appear to be constantly present. Forms of *Serpulites* are found in the Palæozoic rocks from the Ordovician to the Carboniferous inclusive, but their true affinities are by no means certain. The name of *Trachyderma* (apparently the same as the *Scolecoderma* of Salter) was proposed by Phillips for the casts of membranous, flexible tubes which are found in Ordovician and Silurian deposits. These are transversely wrinkled or plaited, and as they are usually found to cross the strata obliquely or vertically, it is probable that they are really Annelidous in their nature.

More remarkable than the preceding is the Ordovician, Silurian, and Devonian genus *Cornulites* (figs. 339, 340), in which the animal was solitary, and inhabited a conical calcareous tube of considerable size. The tube of *Cornulites* (fig. 339) is ringed with well-marked transverse annulations, and is usually ornamented with fine longitudinal striæ. The tube gradually tapers towards its lower end, where it appears to have been attached to foreign bodies, the attachment taking place by the pointed and usually bent initial portion of the tube, and not (as in *Ortonia*) by the whole of one side. Moreover, many adult examples show no signs of having been attached by the pointed base, so that the tube was probably not invariably fixed to foreign bodies, but may have been free. The tube may be three or four inches long, straight or slightly curved, and with a wide

aperture at its broad end. The internal cast of the tube has the form of a series of inverted conical rings, of small width, arranged in an imbricating manner. The most remarkable feature about *Cornulites* is, however, the peculiar micro-structure of the thick calcareous wall. Thin sections of the tube show that it is composed principally of lenticular calcareous vesicles of considerable size (figs. 335, C, and 339, B), resembling in form the vesicles of a Cystiphylloid coral. These vesicles are sometimes traversed by irregular laminated bands or fibrous layers, and a similar layer seems to line the interior, and cover the exterior of the tube. The inner laminated layer (fig. 335, C) is sometimes of considerable thickness, and is



Fig. 339.—*Cornulites serpularius*, from the Wenlock Limestone. A, Tube of the natural size; B, Portion of a cross-section of the tube enlarged. (Original.)

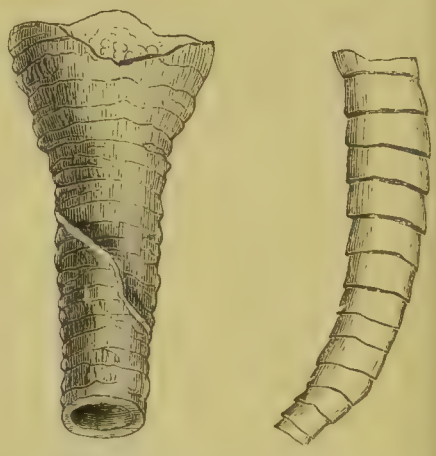


Fig. 340.—*Cornulites* sp. Silurian. The right-hand figure represents a cast of the tube. The left-hand figure represents a specimen broken below. (Original.)

traversed by minute transverse tubuli similar to those seen in the laminated calcareous tissue of some recent *Serpulæ*. As the tube in some *Serpulæ* (fig. 335, B) also shows a vesicular character, the microscopic structure of the tube of *Cornulites* is not so abnormal as it has generally been supposed to be, and its Annelidan nature is, on the whole, rather supported by its minute structure than disproved.

In the genus *Ortonia* (fig. 341) are included conical, slightly flexuous calcareous tubes, which have a general resemblance to *Cornulites*, but are of comparatively small size, and are cemented by the whole of one surface to some foreign body such as a shell or a coral. Though often found in considerable numbers, the tubes are essentially solitary in habit. The tube is ringed with imbricating

annulations, and the free surface of the tube, in some species, appears to have a cellular structure, similar to that which is seen in the tube of *Cornulites*; but the microscopic characters of *Ortonia* have not



Fig. 341.—A, Tubes of *Ortonia conica* growing upon the valve of *Strophomena alternata*, natural size; B, A single tube of the same, enlarged. Ordovician. (Original.)

as yet been worked out. The known species of *Ortonia* are found in the Ordovician, Silurian, Devonian, and Carboniferous rocks. It may be noted in this connection that the tubes of some species of *Ortonia*, except for being attached along one side to foreign bodies, present a considerable general likeness to the tubes of the genus *Tentaculites*, which genus high authorities have regarded as Annelidan. There are, however, important distinctions between these two types, and the genus *Tentaculites* will be considered here under the *Pteropoda*, to which group, in the author's opinion, it is properly referable.

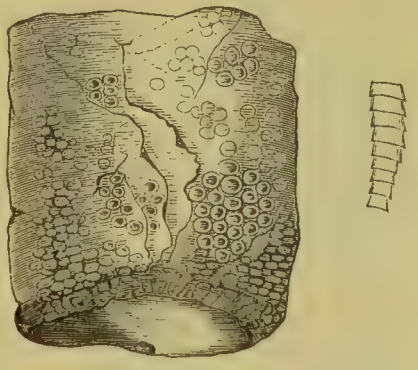


Fig. 342.—*Conchicolites gregarius*, growing upon the shell of an *Orthoceras*. Ordovician. (Original.)

A similar superficial likeness to *Tentaculites* is exhibited by the Ordovician genus *Conchicolites*, which is certainly Annelidan. In this genus (fig. 342) the animal was social, and formed masses of clustered tubes, growing side by side, attached by their bases to the outside of the dead shells of *Orthocerata* or Brachiopods. Each tube is made up of short imbricating rings, each of which partially overlaps the one below. Hence the cast of the tube (the right-hand figure in fig.

342) appears to consist of short conical segments, the broad ends of which are turned away from the mouth of the tube. Though the general aspect of the tubes of *Conchicolites* is very similar to that of *Cornulites*, the micro-structure of the tube is very different in the two genera. In *Cornulites*, as has been shown, the tube has a characteristic vesicular structure (fig. 335, c). On the other hand, thin sections of the tube of *Conchicolites* (fig. 335, d) show it to be devoid of this cellular structure, and to be composed of imbricating calcareous plates, which are fibrous in character, and which overlap in such a way that the broad upper ends of the successive rings are directed towards the interior of the tube.

Sub-order II. Errantia. — The Polychætous Annelides included in this sub-order are free-living animals which do not form for themselves investing-tubes. The body is usually elongated, each segment carrying on its sides tufts of horny setæ, attached to

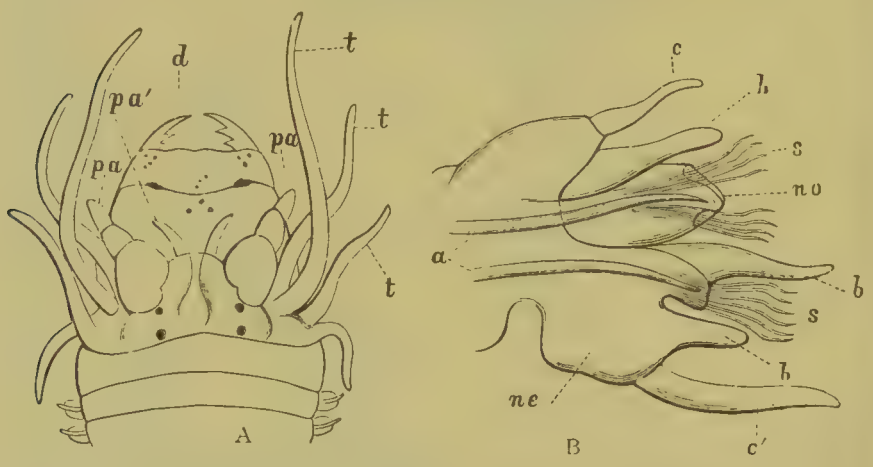


Fig. 343.—A, Head of *Nereis incerta*, viewed from beneath, and enlarged (after Quatrefages): *d*, The principal pair of chitinous jaws (the dark dots on the lobe behind these are smaller denticles); *pa'*, Internal pair of palpi; *pa*, External or greater pair of palpi; *t t t*, Tentacles. B, Foot-tubercle of *Nereis*, enlarged: *no*, Notopodium; *ne*, Neuropodium; *c*, Dorsal cirrhus; *c'*, Ventral cirrhus; *b b b*, Branchial filaments; *a*, Aciculæ; *s s*, Setæ attached to the dorsal and ventral oars.

fleshy, double tubercles or "parapodia" (fig. 343, b). The mouth is furnished with horny or partially calcified jaws (fig. 343, a). The branchiæ are attached to the sides of the body, or to the dorsal surface. Though the integument of the Errant Annelides secretes chitinous matter to a certain extent, a resistant exoskeleton is not developed, the only hard structures present being the chitinous setæ and the horny jaws, the lower pair of the latter (and sometimes the upper pair also) being more or less completely calcified. Owing to the soft nature of their integument and foot-tubercles, it can only be under the most favourable conditions that the actual *body* of an Errant Annelide can be preserved in the fossil state. Specimens

of this nature do, however, occur occasionally in finely-levigated sediments, such as the Lithographic Slates (Jurassic) of Germany and the Eocene Slates of Monte Bolca. Impressions of this kind not only exhibit the form of the body, but may show the lateral setæ (fig. 344) and the jaws in place; and upon such Ehlers founded the genera *Eunicites*, *Lumbriconereites*, and *Meringosoma*, all of which were originally described from the Lithographic Slates (Jurassic) of Germany.

Apart from the comparatively very rare cases in which, as above described, the body of the worm is itself partially preserved, it has been shown by Hinde and others that the horny jaws of Annelides are by no means of rare occurrence even in strata as ancient as the Ordovician, so that the Palæozoic seas must have been tenanted by vast numbers of these animals. The jaws of Annelides (fig. 345) usually present themselves as minute, dark, shining objects, wholly unconnected with one another, or with the remains of the animal to which they originally belonged. Though probably partly calcified, the jaws seem to be in the main composed of chitine, as they are not destroyed by the action of mineral acids. They average about $\frac{1}{12}$ inch in length, but a few reach a length of a third of an inch. In *form*, the jaws are very variable. In one type (fig. 345, A), the jaw is long and narrow, with a series of nearly similar teeth on one margin; in another common form, the jaw is furnished with a powerful anterior hook, which may be immediately succeeded by a series of small teeth, or may have the latter on the straight edge of a wide posterior extension (fig. 345, B); other varieties are in the shape of simple hooks with a wide flange-like extension behind (fig. 345, C); while others are falciform, with a series of small teeth on the curved upper edge. There are other variations in the shape

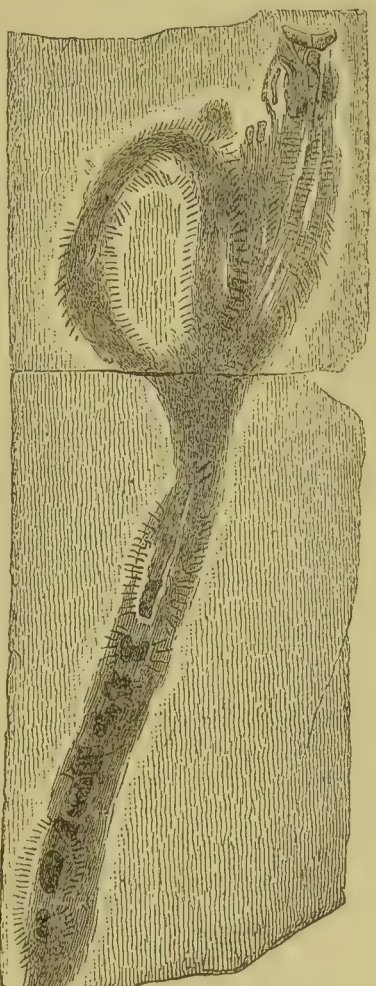


Fig. 344.—The impression of an Errant Annelide (*Eunicites avitus*), from the Lithographic Slates of Eichstadt, of the natural size. (After Zittel.)

of these minute fossils, and owing to the isolated condition in which they occur, it is difficult to refer them to genera and species. Most of the fossil forms resemble the jaws of the living family of the *Eunicea*, and such have been referred to the genera *Eunicites* (fig. 345, A), *Arabellites* (fig. 345, B), *Lumbriconereites*, &c. Others correspond with the recent genus *Glycera*, and have been placed under *Glycerites* (fig. 345, C); while *Nereidavus* appears to represent the existing family of the *Lycoridea*.

As regards their distribution in time, Hinde has shown that these fossil jaws are abundant in some parts of the Ordovician, Silurian, Devonian, and Carboniferous formations; and they are also known to exist in Mesozoic and Tertiary deposits in actual connection

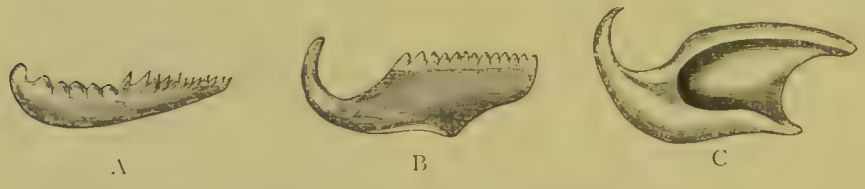


Fig. 345.—Jaws of Annelides from the Ordovician rocks (Cincinnati group) of North America. A, Jaw of *Eunicites varians*, enlarged 3½ times; B, Jaw of *Arabellites cornutus*, enlarged twelve times; C, Jaw of *Glycerites sulcatus*, enlarged fifteen times. (After Hinde.)

with the bodies of their original possessors. If Rohon and Zittel should prove to be correct in their view that the so-called "Conodonts" are really of the nature of the jaws of Annelides, then these minute fossils occur in rocks as ancient as the Upper Cambrian; but the nature of these problematical bodies will be dealt with more fully later on.

Apart from the above-mentioned indubitable remains of Errant Annelides, numerous more or less distinct worm-like markings, which are found in muddy and sandy sediments throughout almost the whole of the series of stratified rocks, have been referred to animals of this group. Some of these (such as *Nereites* and *Phyllodocites*) have been described as being of the nature of the petrified *bodies* of Sea-worms; but as they exhibit absolutely no *structure*, it is in the highest degree improbable that this explanation of their origin is correct. The true nature, in fact, of most of the remains here in question must be regarded as exceedingly uncertain. Some are, probably, really referable to the vegetable kingdom; others are almost certainly formed by Molluscs, or by Crustaceans; others are of entirely dubious affinities; while others are, doubtless, really due to the operation of Errant Annelides. It may be added that the fossil remains which have been referred to Nemertean Worms cannot at present be separated, in any satisfactory manner, from those formed by Errant Annelides. Thus the so-called *Nemertites*

of the Silurian is just as likely to be Annelidan as Nemertean, and the nature of the *Legnodesmus* of the Solenhofen Slates is wholly problematical. In fact, the entire subject of the remains of fossil Errant Annelides is one of the most obscure and difficult with which the palæontologist is called upon to deal; and all that can be done here is to glance at some of the leading points of interest connected with it, under the following heads :—

I. *Burrows of Habitation.*—Various recent Annelides live buried in the sand or mud, between tide-marks or in shallow water, and communicate with the surface by means of a perpendicular shaft or burrow. Such shafts may, for convenience' sake, be termed "burrows of habitation," though the animal forms a fresh one at will, as it moves from one spot to another; and, as a matter of course, they run in a direction more or less opposed to the surfaces of the laminæ of the rock, being often quite vertical. Sometimes

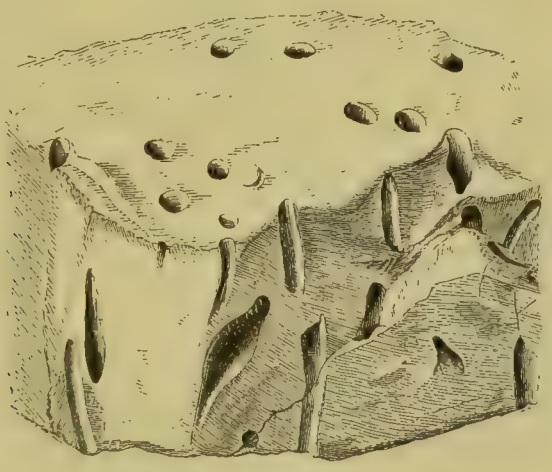


Fig. 346.—Annelide-burrows (*Scolithus Canadensis*) from the Potsdam Sandstone (Upper Cambrian). (After Billings.)

such burrows are hollow, but they are more commonly filled up by the matrix of the rock. Among the genera which have been founded upon remains of this kind are *Scolithus*, *Histioderma*, and *Arenicolites*, all of which occur in rocks of Cambrian or Ordovician age. *Scolithus* is founded upon long burrows, which are nearly straight, and descend vertically through the rock (fig. 346). They often become somewhat widened out superiorly, and are generally found in great numbers together. They occur abundantly in the Potsdam Sandstone (Upper Cambrian), and Clinton formation (Silurian) of North America, and also in the hard sandstones of the Stiper Stones in Shropshire (Ordovician). They have been supposed to have been formed by sea-weeds, but there is little doubt that they

are truly the burrows of Annelides. The somewhat problematical fossil upon which the genus *Histioderma* is founded is described as a curved burrow, from one to nearly four inches in length, terminating in a trumpet-shaped opening, which is placed in the centre of a small mound. The genus *Arenicolites*, again (fig. 347), includes small double burrows, which form loops, shaped like the letter U, opening on the surface by two apertures placed close to one another. The mouths of these burrows are thus placed in pairs, one orifice being supposed to be an aperture of entrance for the worm, and the other one of exit. Burrows of this nature occur abundantly in the Lower Cambrian strata of the Longmynd, and are also far from uncommon in deposits of Ordovician age.

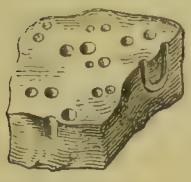


Fig. 347.—Burrows of *Arenicolites didymus*. From the Longmynd (Lower Cambrian).

II. *Wandering Burrows.*—Various recent Annelides, among which the common Lug-worm (*Arenicola piscatorum*) is a notable example, form long, wandering, irregular, and tortuous tunnels in the sand of the sea-shore, at a little distance below the surface. In these cases the worm subsists upon particles of organic matter disseminated through the sand or mud, through which, therefore, it literally eats its way. The burrows thus formed are, consequently, very irregular; they principally have a horizontal direction; if formed by many individuals, they may cross or intersect one another in various ways; and as the worm proceeds on its course, they become filled up in the rear of the advancing animal by the sand which has been passed through the alimentary canal, some of this sand being often voided at some point at the surface to form the tortuous "worm-casts," with which every wanderer on the sea-shore is so familiar. Bodies which we may reasonably assume to be of essentially the same nature as the filled-up "wandering burrows" of worms like the living Lug-worm, are well known to all workers amongst the more ancient, muddy and sandy strata of the earth's crust, and they have received various names, and have had very various origins ascribed to them. They usually present themselves as irregularly cylindrical, worm-like elevations of the surfaces of the strata (fig. 348), which usually are more or less parallel with the laminæ of deposition, but often run somewhat obliquely to these, so as to thread successive laminæ to one another. Generally, they differ slightly in texture and colour from the surrounding rock—as can well be supposed, if their origin be as above described—and from their somewhat superior hardness, they resist disintegration by weathering, and thus come to stand out prominently above the surface. Though they may be much matted together, and may thus appear to branch, it is only in some

cases that they really subdivide. It would appear that many of the fossils of the Palæozoic rocks which have been referred to the Fucoids, under the generic titles *Palæochorda*, *Palæophycus*, &c., may be really the filled-up burrows of wandering marine worms, and such remains may at present be grouped together under the common name of *Planolites*.

While the above explanation will account sufficiently for many of the objects which have been described under the name of *Palæochorda*, and which are here spoken of under the title of *Planolites*, there are many similar fossils for which Nathorst would account in a different and a quite satisfactory manner. It has been shown,

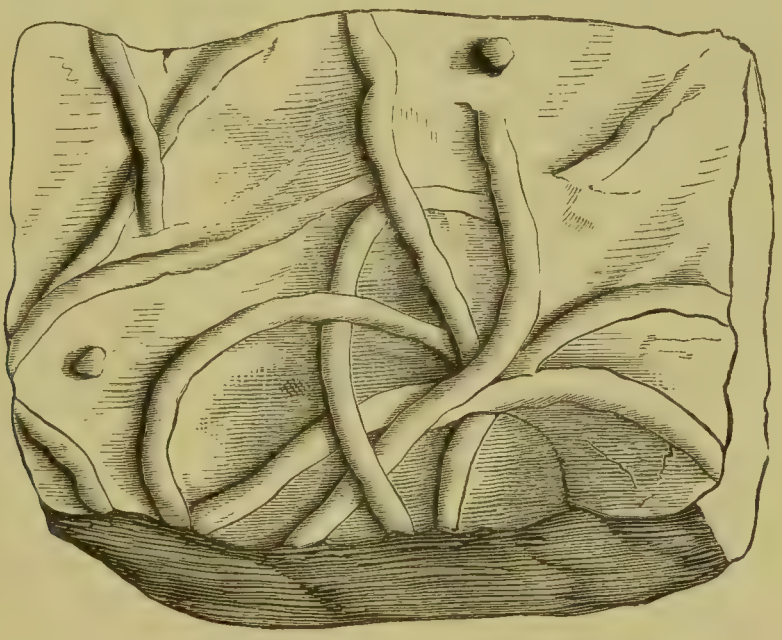


Fig. 348.—*Planolites vulgaris*, the filled-up burrows of a marine worm. Silurian (Clinton Group), Canada. (Original.)

namely, by this well-known observer, that plaster-of-Paris casts of the shallow grooves which worms make in crawling over the surface of fine mud, present cylindrical vermiform markings precisely similar in form and appearance to the fossils here spoken of under the name of *Planolites*. Nathorst therefore concludes that most, if not all, of such fossils are really *convex casts of what were originally grooves or furrows;* and he supports this contention by showing that the worm-like markings in question are found to stand out in demi-relief from the *under surfaces of the strata*. On this explanation—which would probably account satisfactorily for very many of these worm-like fossils—the structures here spoken of would really be of the nature of *tracks*, rather than of filled-up *burrows*. At the

same time, there are undoubtedly some examples which may be regarded as burrows and not as tracks, since there are specimens in which the cylindrical worm-like markings pass obliquely from one lamina to another, instead of being confined to a single surface of deposition. Another point that may be noted in connection with this subject is, that it has been shown by Nathorst that the tracks of certain Annelides upon the surface of mud or sand are *branched*. The fact, therefore, that many of the fossils described under such titles as *Palæochorda* and *Palæophycus* are seen to branch, would not be in itself sufficient to preclude acceptance of the explanation of their origin put forward by Nathorst.

In connection with the burrows of worms, a word may be said as to the curious vermiform bodies which occur abundantly in the Lithographic Slates (Jurassic) of Solenhofen, and which have been described under the name of *Lumbricaria*. The fossils in question are about as thick as a quill in some cases, but in others are only of the dimensions of twine, and they form convoluted and confused elevations on the surface of the beds. They have generally been looked upon as of the nature of casts of the alimentary canal—true "worm-casts" in fact—of marine worms; and, judging from their appearance, this explanation of their nature is probably correct.

III. *Trails and Tracks.*—Lastly, we have to deal briefly with a great group of fossils which have been supposed to be of the nature of the "trails" of Errant Annelides—that is to say, markings formed by the animal dragging its soft body over the surface of wet sand or mud, between tide-marks or in shallow water. Markings of this nature are extremely abundant in many of the older rocks, and in many cases no doubt can be entertained as to their being really the tracks of some marine animal. Even in these cases, however, it is at present impossible, in the majority of instances, to discriminate between the trails produced by Annelides and those formed by Univalve Molluscs or by Crustaceans. There are, nevertheless, certain tracks which may be regarded with considerable probability as Annelidan. This is especially true of the Silurian fossils upon which the genera *Nereites* (fig. 349, B) and *Phyllodocites* (fig. 349, A) have been founded. In these cases we have long, sinuous, and often sharply-bent impressions on the surfaces of the strata, which consist of a central, broader or narrower axis, representing the body of the worm, and of a series of lateral, more or less leaf-like markings, representing the foot-tubercles. These tracks, and others like them, have commonly been supposed to represent the actual *body* of the Annelide, now replaced by mud; but, as before remarked, it is very difficult to conceive of such a replacement, and it is more likely that we have simply the trail of the animal formed by its serpentine wandering over the surface of soft mud.

Another fossil, which is extremely abundant in the Silurian rocks of some localities, and which has generally been supposed to be the

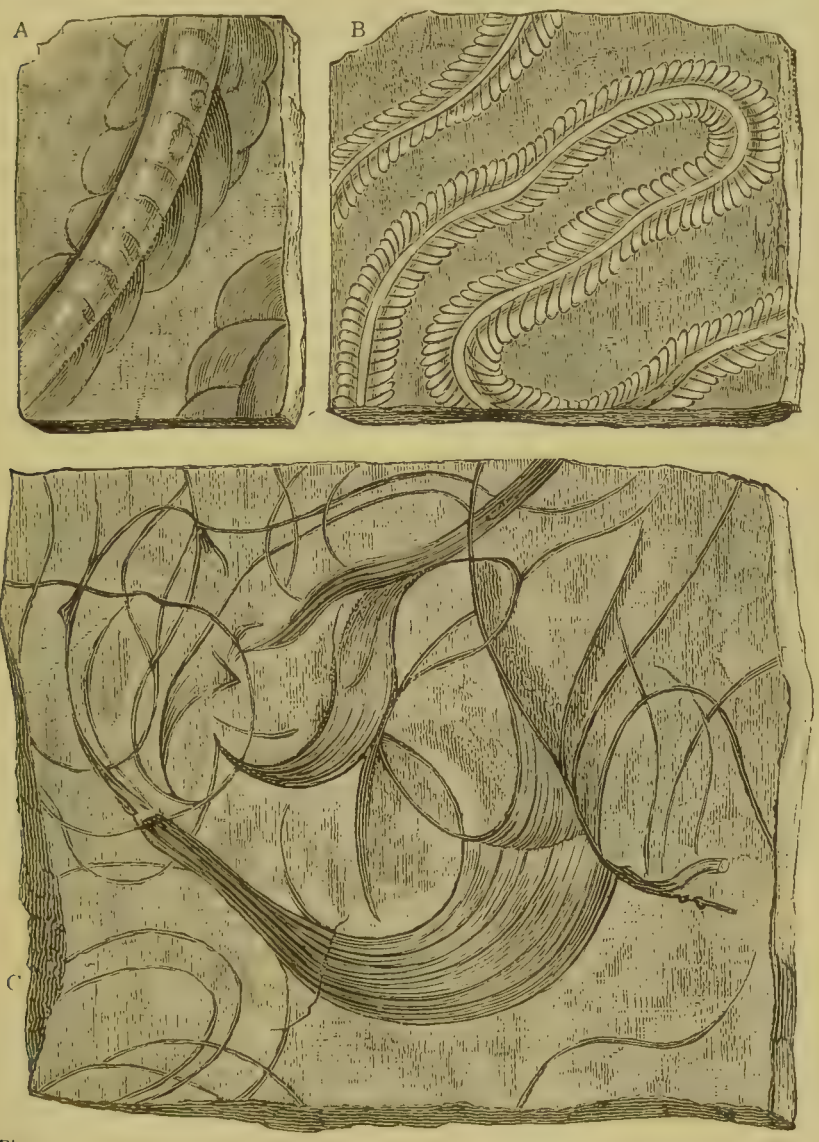


Fig. 349.—A, A small portion of the trail of *Phyllodocites Jacksoni*, from the Silurian slates of Wurtzbach, of the natural size (after Geinitz); B, Small portion of the trail of *Nereites Loomisii*, from the same locality, natural size (after Geinitz); C, Fragment of a slab, showing *Myrianites tenuis*, from the Silurian slates of Thornilee, Peeblesshire, of the natural size. The slab has split at different levels in different parts, and the fossil is seen to cut vertically across the laminæ of deposition, the surfaces thus formed being concentrically striated. (Original.)

track of an Annelide, is *Myrianites*. In ordinary specimens of this genus (fig. 349, C) all that is seen is that the surfaces of the strata are marked by winding and tortuous linear impressions, of extremely

small comparative width, and easily recognisable from the matrix by their darker colour and slightly different texture. These meandering markings wind over the surface of the stone in indefinite undulations, often appearing to cross one another; and no one, looking at such a specimen, would be inclined to doubt that he had to deal with the trails left upon the mud of the sea-shore by some soft-bodied marine animals, though he might question if these could be Annelides. Other specimens, however, of the same fossil, which have been carefully examined by the author, prove conclusively that, in spite of appearances, *Myrianites* is not only not Annelidan in its nature, but that it cannot possibly be the *track* of any animal whatever. It can be shown, in fact, that the narrow serpentine markings upon the surface of the stone, which are universally understood under the name *Myrianites*, are really *the cut edges of thin vertical laminar expansions, sinuously folded, and seen in horizontal section.* In fig. 349, c, a portion of one of the specimens referred to is

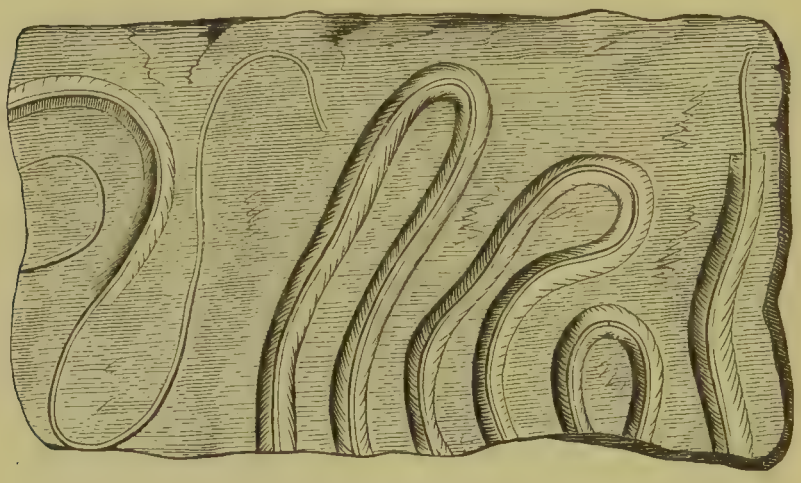


Fig. 350.—*Crossopodia Scotica*, a supposed Annelide track. Silurian. (After M'Coy.)

figured, from which it will be seen that the fossil *cuts directly across the laminæ of deposition*, its actual surface (where exposed by exfoliation of a part of the slab) being marked with concentric striæ. It is therefore quite clear that *Myrianites* was really a thin, erect, folded, leaf-like expansion, of some kind or another, and that what palæontologists have described under this name is only the horizontally-cut edge of this expansion as seen on the surface of the stratum. What *Myrianites* really is, is quite an open question. It is, perhaps, a peculiar form of Fucoid. That it is not Annelidan seems perfectly certain.

Another fossil which has generally been regarded as referable to the Errant Annelides is the *Crossopodia* of M'Coy (fig. 350), also

very abundant in certain Silurian strata. In this fossil there is a central narrow groove, which winds in serpentine bends over the surface of the stone, and is supposed to represent the body of the animal, bounded on each side by a broader and generally ill-defined space, supposed to represent the foot-tubercles. That *Crossopodia*, however, should be the petrified *body* of an Errant Annelide seems almost incredible, and that it is even the *track* of one of these creatures is extremely improbable. In well-preserved specimens of any size, the impressions known under this name are seen to wind backwards and forwards over the stone in a succession of long loops which are placed quite close together, and which could hardly have been produced by any animal in a movement of forward progression. There is, indeed, some evidence that the impressions of *Crossopodia* really cut directly across the laminæ of deposition to some depth, and that they have some direct, though at present not understood, connection with *Myrianites*.

As might have been expected, any fossils which can be supposed with any probability to be the tracks of Annelides, or of other marine animals, present themselves as *depressed* or *concave* markings on the upper surfaces of the strata. The *casts* of these markings, however, are often to be observed on the *under* surfaces of the beds, and these, as a matter of course, present themselves as *convex* or *elevated* impressions. When the beds are vertical, or when the specimens are not found actually *in situ*, it is impossible to distinguish between these two classes of specimens; especially as *some* elevated impressions, supposed to be tracks, do really occur on the *upper* surfaces of the strata. Such impressions, in the opinion of Principal Dawson, "have been left by denudation of the surrounding material, just as footprints on dry snow sometimes remain in relief after the surrounding loose snow has been drifted away by the wind, the portion consolidated by pressure being better able to resist the denuding agency."

As has been already pointed out, however, there is strong reason for accepting the conclusion of Nathorst that many of the elevated worm-like markings that are seen in muddy and sandy sediments are in reality *casts* of grooved tracks or furrows which have been produced by the movements of Annelides and other marine animals over fine silt.

Before leaving this obscure subject finally, it may be well to notice briefly one or two considerations which bear upon the question of the origin and real nature of markings such as we have been considering. In the first place, the late Mr Albany Hancock, in an extremely able memoir, advocated the view that the vermiform fossils of the older rocks may have been, in general at any rate, produced by *Crustaceans*. He showed that similar markings are

produced, at the present day, by small Amphipod Crustaceans (*Sulcator arenarius* and *Kröyera arenaria*), which burrow immediately below the sand on the sea-shore, and give rise to the following appearances: (1.) Large tracks, about 3-8ths of an inch wide, slightly raised, ribbon-like in shape, with a median groove, often intricate and convoluted, sometimes knotted, and several feet in length; (2.) Narrow wedge-shaped furrows, 2-10ths of an inch wide, winding capriciously and often abruptly over the surface; (3.) Nodulated or articulated tracks, consisting of a small furrow, with a rounded ridge on one side. Mr Hancock showed that tracks of these three kinds are actually produced by the above-named small Crustaceans, which burrow beneath the sand, but a short way below the surface, "the arch or tunnel thus formed partially subsiding, as the creature moves forwards, and breaking along the centre," thus giving rise to a median groove. There is no doubt that the phenomena so carefully observed by Mr Hancock throw considerable light upon the subject of the supposed Annelide tracks of muddy and sandy sediments; but there is room for much hesitation before concluding that any of these tracks, in the older rocks at any rate, were really formed by Crustaceans like the living *Sulcator arenarius*. One ground for such hesitation need alone be brought forward here—namely, that the so-called "Annelide-tracks" of the older Palæozoic rocks often occur in vast numbers, in finely-levigated deposits, and throughout a thickness of sometimes hundreds of feet of strata, and that it is almost inconceivable that traces of the makers should not have been detected in the same beds, supposing them to have been formed by animals which, like Crustaceans, have a skeleton highly susceptible of preservation in the fossil condition.

In the second place, there are good grounds for ascribing certain forms of "tracks," which have often been regarded as Annelidous, to the operation of Univalve Molluscs. It is well known that many Gasteropods, in crawling over the surface of sand or mud, give rise to sinuous or intercrossing trails, the general feature of which is the presence of a median furrow or groove, which may or may not be bordered by a series of lateral markings on each side. Thus, the annexed engraving (fig. 351) shows the track of a common living Gasteropod (*Purpura lapillus*) when moving over firm sand, and it will be at once seen that the markings produced by this Univalve are exceedingly similar to the supposed Annelide-trails upon which the genus *Crossopodia* has been founded, both consisting of a central groove, bounded by lateral raised margins. While it may therefore be regarded as very probable that some supposed worm-tracks have been formed by Molluscs, it cannot be altogether overlooked that we do not usually meet with the fossil shells of such Molluscs in

the deposits in which the trails occur, as we might reasonably expect to do.

Principal Dawson, again, suggests "that Algæ and also land-plants, drifting with tides and currents, often make the most remarkable and fantastic trails," which might easily be mistaken for the

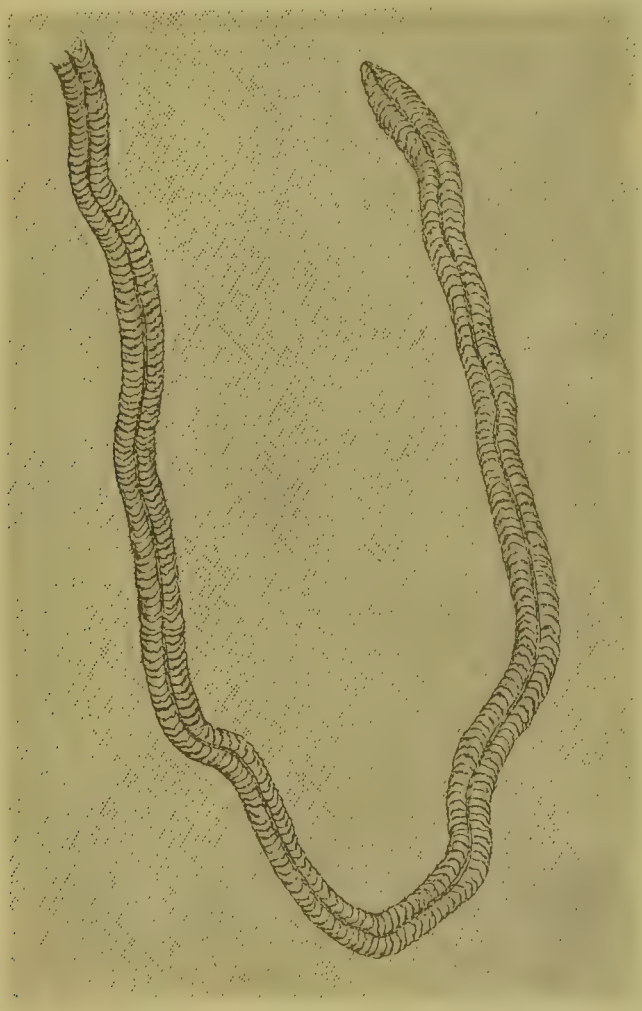


Fig. 351.—Track of the living *Purpura lapillus* on firm sand, reduced three diameters. (From a drawing made by the late Robert Gray.)

tracks of Annelides. This suggestion is a very valuable one, but certainly will not explain the origin of the majority of the so-called "Annelide-tracks" of the Palæozoic rocks, the regular serpentine form of which is one of their most remarkable features.

Lastly, some observers are disposed to see in these supposed tracks and trails the remains of various forms of *Algæ*, the drifted

stems of which, lying on the surface of mud or sand, have, by their slow decay, given rise to the worm-like markings which we have been here considering. The evidence in favour of this view does not appear to be satisfactory, but it is impossible to pursue further this intricate subject in this place. The student desirous of fuller information on this difficult question may be referred more particularly to the important and beautifully illustrated memoir which Professor Nathorst has published upon the tracks and markings produced by various living forms of Invertebrates.

LITERATURE.

1. "A Contribution to the Study of the British Carboniferous Tubicolar Annelides." 'Geological Magazine.' 1880. R. Etheridge, jun.
2. "Notes on the Annelida Tubicola of the Wenlock Shales." 'Quart. Journ. Geol. Soc.,' vol. xxxviii. 1882. Vine.
3. "Cornulites, Tentaculites, and Conchicolites." Nicholson. 'Amer. Journ. Sci. and Arts.' 1872.
4. "On the Genus Ortonia." Nicholson. 'Geol. Mag.,' Dec. 1, vol. ix. 1872.
5. "Ueber fossile Würmer aus dem lithographischen Schiefer in Bayern." 'Palæontographica,' Bd. xvii. 1867-70. Ehlers.
6. "On Annelide Jaws from the Cambro-Silurian, Silurian, and Devonian Formations in Canada, and from the Lower Carboniferous in Scotland." 'Quart. Journ. Geol. Soc.,' vol. xxxv. 1879. Hinde.
7. "On Annelide Jaws from the Wenlock and Ludlow Formations of the West of England." 'Quart. Journ. Geol. Soc.,' vol. xxxvi. 1880. Hinde.
8. "On Annelide Remains from the Silurian Strata of the Isle of Gotland." 'Bihang till K. Svenska Vet.-Akad. Handlingar,' Bd. vii. 1882. Hinde.
9. "Ueber Conodonten." 'Sitzungsberichte d. k. bayr. Akad. d. Wiss.' 1886. (Maintaining the view that the "Conodonts" are the jaws of Annelides.) Rohon and Zittel.
10. "Om Spår af några Evertebrerade Djur M. M. och deras Palæontologiska Betydelse (On the Tracks of some Invertebrate Animals and their Palæontological Significance)." 'Kongl. Svenska Vetenskaps-Akad. Handlingar.' 1881. Nathorst.
11. "Palæontology of New York," vols. i. and ii. 1843 and 1852. Also vol. vii. Suppl. 1888. James Hall.
12. "Fossils of the Longmynd." Salter. 'Quart. Jour. Geol. Soc.,' vol. xiii. 1857. Also 'Mem. Geol. Survey,' vol. iii., Appendix. 1866.
13. "Vermiform Fossils from the Mountain Limestone." Albany Hancock. 'Ann. and Mag. Nat. Hist.,' ser. 3, vol. ii. 1858.
14. "The Taconic System." Emmons. 1844.
15. "The Silurian System." Murchison. 3d ed. 1859. (Description of Annelides by Macleay.)
16. "Petrefacta Germaniæ." Goldfuss. 1826.
17. "Ueber ein Æquivalent der takonischen Schiefer Nord-Amerikas in Deutschland." Geinitz and Liebe. 'Verhandl. d. k. Leopold. Carolin. deutsch. Akad. 1867.
18. "Impressions and Footprints of Aquatic Animals on Carboniferous Rocks." Principal Dawson. 'Amer. Journ. Sci. and Arts.' 1873.

CHAPTER XXVIII.

ARTHROPODA.

Crustacea.

The division of the *Arthropoda* or "Articulate Animals" comprises the four great classes of the *Crustacea* (Lobsters, Crabs, &c.), the *Arachnida* (Spiders and Scorpions), the *Myriopoda* (Centipedes and Millepedes), and the *Insecta* (the Insects properly so called), and is distinguished as follows :—

The body is composed of a series of segments or "somites," which are usually definite in number, and which are arranged along a longitudinal axis. Each segment may be provided with a single pair of appendages, and these are always jointed, and are articulated to the body. Both the segmented body and the articulated appendages are, as a rule, furnished with a chitinous, often more or less extensively calcified, exoskeleton, formed by a hardening of the integument. The appendages are hollow, and the muscles are prolonged into their interior. The nervous system consists, typically, of a double chain of ganglia placed along the ventral surface of the body, united by longitudinal commissures, and traversed anteriorly by the œsophagus. The heart, when present, is situated dorsally. When distinct respiratory organs are present, they may be in the form of gills or branchiæ, or they may be saccular or tubular involutions of the integument (pulmonary sacs or tracheæ) adapted for breathing air directly.

If the King-crabs and the Eurypterids be retained in the *Crustacea*, then the classes of the *Arachnida*, *Myriopoda*, and *Insecta* comprise those Arthropods which breathe air directly, and which are thus, in general, adapted for a terrestrial life. On the other hand, the *Crustacea* are essentially water-breathing animals, and even those forms which are terrestrial in their habit, possess respiratory organs in the form of branchiæ. From their generally aquatic mode of life, and the usually more resistant character of their exoskeleton, the *Crustacea* are more abundantly represented in the

fossil condition than is any of the other classes. All the four great classes of Arthropods are, however, known to have been in existence in rocks as old as the Silurian, while the Crustaceans were thoroughly differentiated in the Cambrian period. It is, therefore, clear that the point of divergence of the four primary groups of Arthropods must be sought for in a period long anterior to the Cambrian; and it is hardly probable that we shall ever become acquainted with the primitive form from which the "phylum" of the *Arthropoda* took its origin.

Class I. Crustacea.

The class of the *Crustacea* may be generally defined as comprising *Arthropods which are essentially water-breathers, and usually are provided with gills or branchiæ. The segments of the body are usually definite in number, and some of them almost invariably carry jointed appendages. The head, typically, carries two pairs of antennæ; some of the appendages are modified to act as masticating organs; and the segments of the abdomen are commonly furnished with locomotive appendages. The body is protected by a chitinous or partially calcified exoskeleton or "crust," and the number of ambulatory limbs is mostly from five to seven. The Crustacea, in general, pass in development through a distinct metamorphosis, but the nature of this differs in different cases.*

The body of a typical Crustacean, such as a Lobster, generally exhibits a division into three regions—a *head*, a *thorax*, and an *abdomen* — each of which is composed of a certain number of somites, which may be free, or may be more or less indistinguishably fused with one another. Very commonly, the segments of the head and thorax are united together into a "cephalothorax," which may be protected by a common shield or "carapace" (fig. 352, *ca*). The segments of the abdomen may be separate and movable on one another, or a smaller or larger number of the terminal segments may be fused to form a caudal shield or "pygidium." The last segment of the abdomen (fig. 352, *t*) is known as the "telson," and is generally without appendages, while the anus opens on its lower surface. The "telson" has been variously regarded as an unpaired *appendage*, as a *segment* devoid of appendages, or as representing an aborted *region* of the body, the latter being the view which, on various grounds, seems to be the most probable one.

Each segment of the body of a Crustacean may be regarded as essentially composed of a convex upper plate ("tergum"), closed below by a flatter ventral plate ("sternum"), the line where the two unite being produced downwards and outwards, or

outwards only, into a plate which is known as the "pleuron" or "pleura" (fig. 353). Each segment of the body may carry a pair of appendages (even the telson being sometimes furnished with such); and the typical appendage of the *Crustacea* consists of an undivided basal portion, or "protopodite," to which are attached two diverging branches (fig. 353). The outer of these branches is termed the "exopodite," and the inner the "endopodite"; but one or other, or both, of these terminal divisions of the appendage may be suppressed.

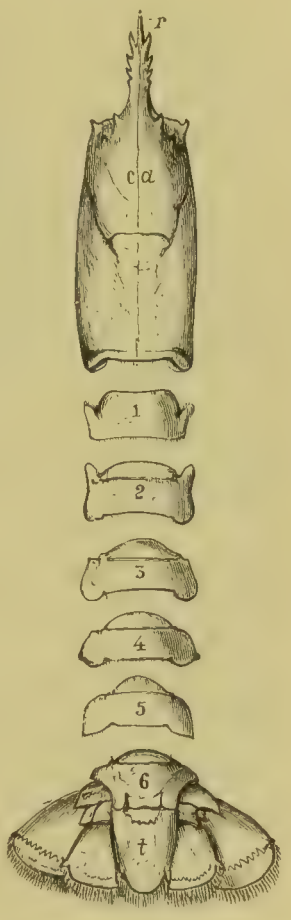


Fig. 352.—Lobster with all the appendages except the terminal swimmerets removed, and the abdominal somites separated from one another. *r*, "Rostrum"; *ca*, Carapace, covering the cephalic and thoracic segments. 1 to 6, The first six segments of the abdomen. No. 6 carries the last pair of swimmerets. *t*, Telson.

The head in the *Crustacea* as a rule carries in front a pair of eyes, which in the higher forms are "compound," being made up of a variable number of separate lenses united side by side. The eyes may be fixed directly to the head, as in the "Sessile-eyed" Crustaceans (*Hedriophthalmata*), or may be carried upon longer or shorter movable peduncles, as in the "Stalk-eyed" Crustaceans (*Podophthalmata*). Behind the eyes, the head carries, in general, two pairs of jointed feelers or "antennæ," the first pair ("antennules") being comparatively small, while the hinder pair ("great antennæ") is of larger size. The segments immediately posterior to this carry three pairs of jaws—the "mandibles," and the first and second pairs of "maxillæ." All these are modified appendages, and therefore are in pairs, and work from side to side. The mandibles constitute the most powerful pair of jaws, and consist usually of a strong toothed protopodite to which a short endopodite (the "mandibular palp") is attached. Between the bases of the mandibles is the aperture of the mouth, bounded in front by an undivided chitinous plate (the "hypostome" or "labrum"), and behind by a usually forked lower lip or "metastoma." The first pairs of thoracic appendages are generally intermediate in structure between walking-legs and jaws, and constitute what are known as "foot-jaws" or "maxillipedes"; while the hinder ones are more especially devoted to locomotion. The thoracic appendages vary, however, extremely in form and

structure in different groups of the Crustaceans. In the Decapod Crustaceans five pairs of the thoracic appendages are in the form of walking-legs; while other groups (such as the Isopods) have seven pairs of ambulatory limbs; and in others, again, the number of locomotive thoracic limbs may be greater or less than the above. The abdominal appendages are very variable in form and function, but they are mostly primarily concerned in locomotion, though often modified to serve as respiratory organs, or, in the females, carrying the eggs.

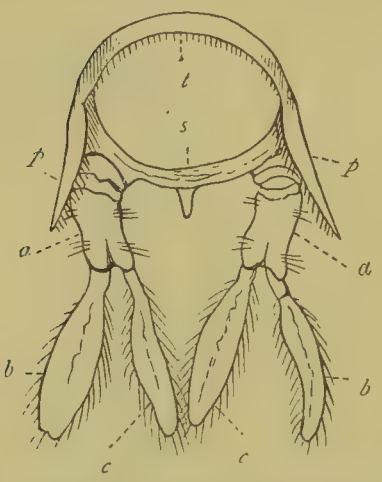


Fig. 353.—The third abdominal somite of the Lobster, separated. *t*, Tergum; *s*, Sternum; *p*, Pleura; *a*, Protopodite of the appendage; *b*, Exopodite; *c*, Endopodite.

As regards their classification, the *Crustacea* may be divided into the two primary sections of the *Entomostraca* and the *Malacostraca*. The first of these includes a great number of comparatively simple Crustaceans, in which the number of the segments and appendages is very variable, sometimes rising above the normal, and sometimes falling below it. The second division includes the more highly organised Crustaceans, in which the number of the segments and appendages is definite. The Cirripedes (with the *Rhizocephala*) may be provisionally regarded as a third division under the name of *Anchoracephala*, characterised by the fact that the adult is attached to foreign bodies by the metamorphosed head. The orders included in these three divisions are shown in the following table:—

Sub-class I. Anchoracephala.

Order 1. *Cirripedia.*

Sub-class II. Entomostraca.

Order 1.	*Ostracoda.*	*Legion*, Lophyropoda.
„ 2.	*Copepoda.*	
„ 3.	*Cladocera.*	*Legion*, Branchiopoda.
„ 4.	*Phyllopoda.*	
„ 5.	*Phyllocarida.*	
„ 6.	*Trilobita.*	
„ 7.	*Xiphosura.*	*Legion*, Merostomata.
„ 8.	*Eurypterida.*	

Sub-class III. Malacostraca.

Division A. Hedriophthalmata.

Order 1. *Amphipoda.*
„ 2. *Isopoda.*

Division B. Podophthalmata.

Order 1. *Cumacea.*
„ 2. *Stomatopoda.*
„ 3. *Schizopoda.*
„ 4. *Decapoda.*

As regards the general distribution of the *Crustacea* in time, remains of animals belonging to this class are abundant in the fossiliferous formations generally, from the Cambrian onwards. Nor are these remains confined to purely marine formations, since many Crustaceans are inhabitants of fresh or brackish waters, and the remains of such are of common occurrence in lacustrine or estuarine deposits. The most ancient group of the Crustaceans is that of the Trilobites, which is represented early in the Cambrian period, and continued to exist till the close of Palæozoic time (Permian). Nearly as old a group is that of the *Phyllocarida*, the latest representatives of which appear in the Trias. The Eurypterids, again, like the Trilobites, are exclusively Palæozoic, the earliest forms of this group appearing in the Ordovician period. Most of the other orders of Crustaceans appear to have come into existence within the limits of the Palæozoic period, though some doubt may be felt as to the systematic position and affinities of some of the ancient forms which have been referred to certain of the higher orders of the class. The Decapod Crustaceans, which represent the highest stage of development in the class, have their beginnings in the Palæozoic period, but they do not attain a dominant position till the Mesozoic deposits are far advanced, and they have attained their maximum at the present day.

Sub-class I. Anchoracephala.

Order Cirripedia.

The order of the *Cirripedia* includes a series of aberrant Crustaceans, of which the most familiar forms, and the only ones which occur in the fossil condition, are the Acorn-shells and their allies (*Balanidæ* and *Verrucidæ*) and the Barnacles (*Lepadidæ*). The essential feature of the order is that *the larva has the form of a free-swimming "nauplius," but the adult is fixed by means of its modified antennæ, and is enclosed in an integumentary sac, within*

which a many-valved shell is typically developed. The abdomen is rudimentary, and the thorax usually carries six pairs of multiarticulate limbs ("cirri"), each of which consists of a protopodite carrying a long, jointed endopodite and exopodite.

The typical *Cirripedia* are distinguished by the fact that in the adult condition they are permanently fixed to some solid object by the anterior extremity of the greatly metamorphosed head; the first three cephalic segments being much developed, and enclosing the rest of the body. The larva is free and locomotive, and the subsequent attachment, and conversion into the fixed adult, is effected by means of a peculiar secretion, or cement, which is discharged through the antennæ of the larva, and is produced by special cement-glands. In the *Cirripedia*, therefore, the head of the adult is per-

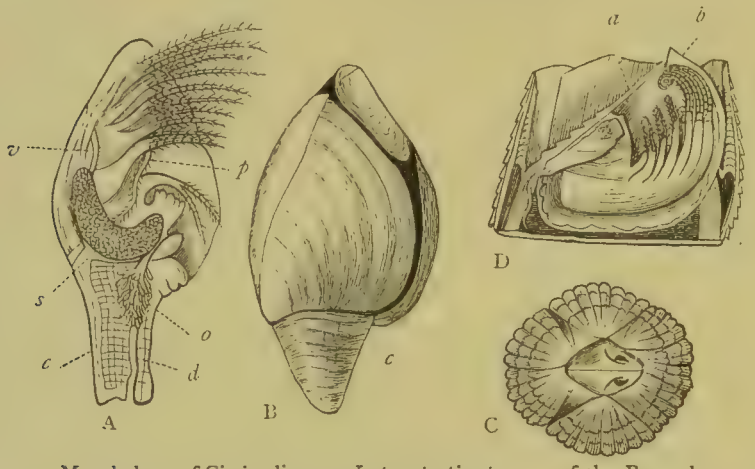


Fig. 354.—Morphology of Cirripedia. A, *Lepas pectinata*, one of the Barnacles, one side of the shell being removed, enlarged four times: *c*, Peduncle; *d*, Cement-duct; *o*, Ovary; *s*, Ovisac; *v*, Vas deferens; *p*, Penis. B, *Pœcilasma fissa*, enlarged five times; *c*, Peduncle. C, *Balanus balanoides*, viewed from above, of the natural size. D, *Balanus tintinnabulum*, with the shell on one side removed to show the animal; *a*, One of the valves ("scutum") of the operculum; *b*, Another valve ("tergum") of the operculum. (After Darwin and Pagenstecher.)

manently fixed to some solid object, and the visceral cavity is protected by an articulated calcareous shell, or by a coriaceous envelope (fig. 354). The posterior extremity of the animal is free, and can be protruded at will through the orifice of the shell. This extremity consists of the rudimentary abdomen, and of six pairs of forked, cirrated limbs, fringed with hairs, which are attached to the thorax, and serve to provide the animal with food. The two more important types of the *Cirripedia* are the Acorn-shells (*Balanidæ* and *Verrucidæ*) and the Barnacles (*Lepadidæ*). In the former the animal is sessile, the larval antennæ, through which the cement exudes, being embedded in the centre of the membranous or calcareous "basis" of the shell. In the latter the animal is stalked, and consists of a "peduncle" and a "capitulum." The peduncle consists of the

anterior extremity of the body, with the larval antennæ, usually cemented to some foreign body. The capitulum is supported upon the peduncle, and consists of a case composed of several calcareous plates, united by a membrane, enclosing the remainder of the animal.

The group of the *Rhizocephala* differs in many respects from that of the typical Cirripedes, cement-glands being absent, and the animal being fixed parasitically to the bodies of other Crustaceans by means of branched root-like processes derived from the metamorphosis of the antennæ, while the alimentary canal and limbs are absent.

The order of the *Cirripedia* is divisible into four principal divisions—the *Thoracica*, the *Abdominalia*, the *Apoda*, and the *Rhizocephala*—of which only the sub-order of the *Thoracica* is known to possess fossil representatives. This sub-order includes the Acorn-shells and Barnacles, in which the body is protected by a more or less complete calcareous shell; and as it is with the shell that the palæontologist has to deal, some details must be given as to its general structure.

As regards the microscopic structure of the shell, the calcareous tissue of the exoskeleton is exceedingly hard and compact, and shows in thin sections a finely granular structure. In the Lepadoids the shell-structure is very dense, with an obscure fibrous arrangement, but in many Balanoids a coarse cellular or tubular structure is present, the tubes being of large size, and being crossed by transverse partitions.

In the symmetrical Sessile Cirripedes or *Balanidæ*, commonly known as Acorn-shells, the animal is protected by a calcareous shell formed by calcifications within the walls of the first three cephalic segments. The animal is placed within the shell, head downwards, and is fixed to the centre of a shelly or membranous plate, which closes the lower aperture of the shell, and which is termed the "basis" (fig. 355, A, *l*). The "basis" is fixed by its outer surface to some foreign object, and is sometimes compact, sometimes porous. Above the basis rises a limpet-shaped, conical, or cylindrical shell, which is open at the top, but is capable of being completely closed by a pyramidal lid or "operculum." Leaving the operculum out of consideration at present, the sides of the shell are seen to be composed of from four to eight separate pieces or valves, or, as they are technically called, *compartments*. These compartments are usually closely contiguous by their lateral margins, and are separated by lines of division or "sutures"; but they are sometimes anchylosed together. Each compartment consists of a main central portion, which is termed the "paries" (fig. 355, B, *p*), and which is attached below to the "basis" of the shell. The "paries" grows downwards, so that the whole shell increases by additions made

round the base. The paries of each compartment is flanked by wing-like portions, which differ from the paries in appearance, and are called "radii" and "alæ," according to their shape (fig. 355, B, C). Sometimes the paries has a "radius" on both sides, sometimes "alæ" on both sides, and sometimes an ala on one side and a radius on the other.

The separate compartments of the shell receive special names according to their position. The compartment at the end of the shell where the animal thrusts out its cirrated limbs, is called the "carina" (fig. 355, A); and the compartment immediately opposite to this the "rostrum." The remaining compartments are "lateral," the one nearest the carina "carino-lateral," the one nearest the rostrum "rostro-lateral," and the middle one simply "lateral" (fig. 355, A); but the three rarely coexist.

The "operculum" or lid of the shell consists of two pairs of valves, known as the "scuta" and "terga," forming a little pyramid or cone, attached within the orifice of the shell by a membrane. Each scutum opens and shuts against its fellow along one margin (the "occludent" margin), and articulates with one of the terga

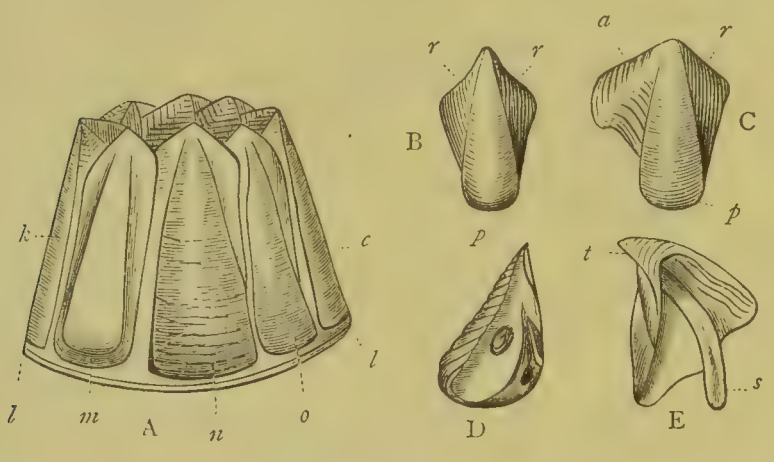


Fig. 355.—Shell of Balanidæ. A, Diagram of the shell of *Balanus*: *l l*, Basis; *c*, Carina; *k*, Rostrum; *m*, Rostro-lateral compartment; *n*, Lateral compartment; *o*, Carino-lateral compartment. B, Compartment with two radii (*r r*), flanking the paries (*p*). C, Compartment with a radius (*r*) on one side, and an *ala* (*a*) on the other side of the paries. D, Internal view of the scutum. E, Internal view of the tergum, showing the spur (*s*) and the beak (*t*). (After Darwin.)

along the opposite margin. Similarly, each tergum opens and shuts against its fellow along one margin (the "carinal" margin), and articulates with one of the scuta along the opposite margin. The apex of the terga (fig. 355, E) often forms a prominent beak, and the basal margin is furnished with a process or "spur." The scuta and terga are not only movable, but are furnished with proper depressor muscles.

As regards the *geological distribution* of the *Balanidæ*, the oldest known types are the *Protobalanus* and *Palæocreusia* of the Devonian rocks of North America. The former of these is a minute Balanoid which possessed the unique peculiarity that the shell consists of no less than twelve compartments (the "rostrum," the "carina," and five pairs of "lateralia"). In the genus *Palæocreusia*, again, the shell was embedded in the substance of the corallum of *Favosites*, and the compartments of the shell are fused to form a single undivided plate, covering a tubular sub-cylindrical basis.

With the above-mentioned exceptions, no Palæozoic representatives of the Balanoids have hitherto been recognised, the *Balanus carbonarius* of the Carboniferous rocks of Saxony being, according to Zittel, not a Cirripede at all. In the Mesozoic rocks, moreover, no undoubted representative of the Balanoids is known till the Upper Chalk is reached, a species of *Chthamalus* appearing in this formation. The fossil described by Seeley as a Balanoid from the

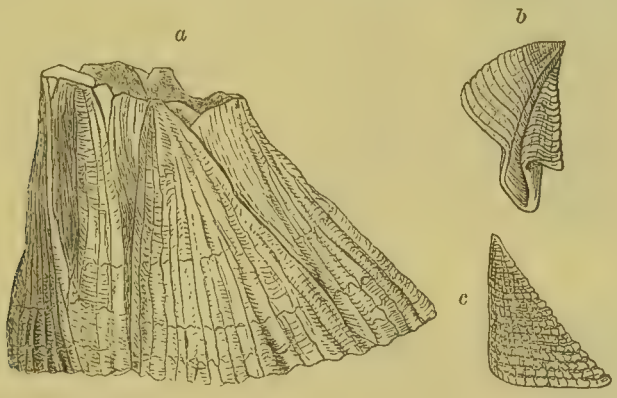


Fig. 356.—*Balanus concavus*, of the natural size, from the Pliocene Tertiary (Crag). *a*, Side-view of the shell; *b*, Tergum; *c*, Scutum. (After Darwin—copied from Zittel.)

Lias, under the name of *Zoocapsa*, does not appear to be properly referable to this group. In the Tertiary rocks, the remains of Balanoids are not uncommon, the recent genus *Balanus* (fig. 356) occurring in deposits as old as the Eocene, and being still more abundantly represented in the Oligocene, Miocene, and Pliocene. In the later Tertiaries the group is further represented by forms belonging to the genera *Chthamalus*, *Acasta*, *Pyrgoma*, and *Coronula*, all of which are known by living types.

The remaining family of the Sessile Cirripedes is that of the *Verrucidæ*, comprising only the single genus *Verruca*. In many respects the *Verrucidæ* approach the *Balanidæ*, but the shell is composed of six valves only, and is unsymmetrical, whilst the scuta and terga (forming the operculum), though movable, are not furnished with a depressor muscle. The *Verrucidæ* appear, so far as

is known, to have commenced their existence towards the close of the Secondary period, the Chalk having yielded two species. *Verruca Strömia* is found in the Coralline and Red Crags (Pliocene), in Glacial deposits, and in existing seas.

The third family of the *Cirripedia Thoracica* is that of the *Lepadidæ* or Pedunculated Cirripedes, commonly known as "Barnacles." In these (fig. 357) the animal differs from the Sessile Cirripedes in having its anterior extremity greatly elongated, forming a stalk or "peduncle" by which it is fixed to some foreign object. At its free extremity the peduncle bears the "capitulum," which corresponds to the shell of the Balanoids, and is composed of various calcareous pieces, united by a membrane, moved upon one another by appropriate muscles, and protecting in their interior the body of the animal with its various appendages. The peduncle is cylindrical, of varying length, flexible, and furnished with proper muscles. In some species the peduncle is naked, and cannot be preserved in the fossil condition; but in other cases the peduncle is furnished with calcareous scales (*Loricula* and *Turrilepas*, fig. 359), in which case it is readily preserved. The "capitulum" (fig. 358), as before said, corresponds with the shell of the *Balani*, and is generally much flattened. It consists ordinarily of five or more valves united to one another by membrane, usually with marked interspaces; but the valves may be rudimentary or wanting, and the entire capitulum may be membranous. The parts of the capitulum correspond ideally with the parts of the shell in the Balanoids. In the latter, however, the shell is for the most part composed of the "compartments," and the "operculum" is comparatively small and insignificant. In the Lepadoids, on the other hand, the valves which correspond with the operculum of the Balanoids are disproportionately developed, and the valves which correspond with the compartments of the Balanoids are much less conspicuous, and are often partially absent. The most important and persistent of the valves are the "scuta" (fig. 358, *b*), which protect the front part of the body, and correspond with the valves bearing the same name in



Fig. 357.—*Lepas anserifera*, a recent Pedunculated Cirripede. The lower figure shows the scutum detached.

the operculum of the Balanoids. The next most important are the "terga" (fig. 358, *a*), which protect the dorso-lateral surface. A pair of scuta and a pair of terga are present, and these are the largest of all the valves. The "carina" and "rostrum" are placed along the edges of the capitulum, the former being much the most important; and there may be a "sub-carina" and "sub-rostrum." The remaining valves, with the carina and rostrum, correspond with the proper shell of the Balanoids; but they are often wanting or rudimentary, and they require no further consideration here.

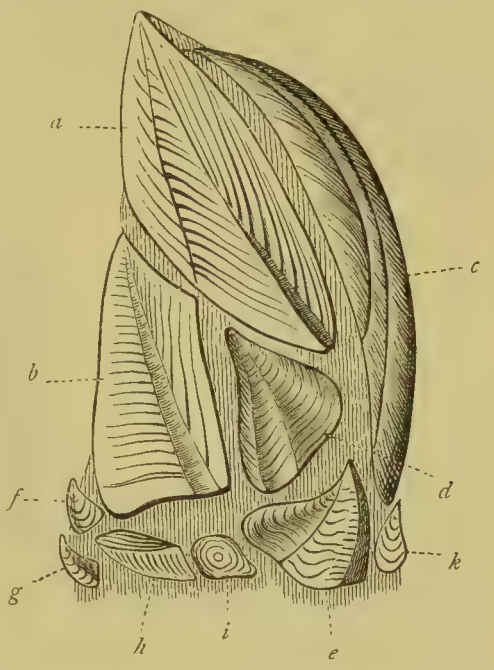


Fig. 358.—Capitulum of a Pedunculated Cirripede. *a*, Tergum; *b*, Scutum; *c*, Carina; *d*, Upper latus; *e*, Carino-latus; *f*, Rostrum; *g*, Sub-rostrum; *h*, Rostral latus; *i*, Infra-median latus; *k*, Sub-carina. (After Darwin.)

As regards the distribution of the Lepadoid Cirripedes in time, the oldest known types belong to the genus *Turrilepas* (=*Plumulites*), several forms of which have been detected in the Ordovician, Silurian, and Devonian formations. In this singular genus (fig. 359, *a*) are included elongated bodies covered with from four to six intersecting rows of calcareous plates. The plates are triangular in form, with a curved lower margin, and marked with transverse striæ; those of the median series being keeled. When detached and occurring in an isolated condition (fig. 359, *a*), these plates are not unlike the shells of certain Pteropods, while they may be, and have been, mistaken for the plates of Chitons. They are also not very unlike the plates of some Cystideans (*Ateleocystites*). By Barrande, *Turrilepas* was regarded as the capitulum of a Lepadoid, in which there was either no peduncle or a short one; but Dr Henry Woodward is probably correct in the view that the fossils really represent a scaly peduncle similar to that of the genus *Loricula*, and that the capitulum is still unknown. On the other hand, the *Strobilepis* of the Devonian rocks of North America seems to be really founded upon the capitulum of a Lepadoid. Allied to *Turrilepas* is the Silurian genus *Anatifopsis*, of which only the

detached valves are known, these being somewhat quadrilateral in shape, and having the lower part of the base marked out into one or two horizontal segments, which are more or less separated from the body of the valve. In the Carboniferous and Permian rocks no Lepadoids are known, but the genus *Pollicipes* is represented in the later Triassic (Rhætic deposits). Other forms of *Pollicipes* are Jurassic, but the genus attained its maximum of development in the Cretaceous period, at which time the group of the Lepadoids seems to have reached its culminating point. Tertiary species of *Pollicipes* are also known, and the genus survives at the present

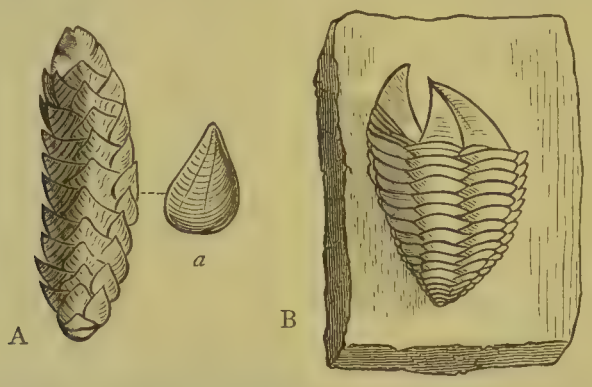


Fig. 359.—A, *Turrilepas* (*Plumulites*) *Wrightii*—Silurian. (After Woodward.) *a*, A plate of the same magnified. B, *Loricula pulchella*—Chalk. (After Darwin.)

day. Some Jurassic types formerly ascribed to *Pollicipes* have been separated by Zittel to form the genus *Archæolepas*. The genus *Loricula* is wholly Cretaceous, and comprises forms with a small capitulum and a short, plated peduncle (fig. 359, B), the organism being attached by one side to the shells of Ammonites. The extensive genus *Scalpellum* has numerous living types, and also about thirty fossil representatives, of which the oldest appears in the Cretaceous rocks. On the other hand, the recent genus *Lepas* (*Anatifa*) is not certainly known to occur in the fossil condition, even in the late Tertiary or Quaternary deposits, though the allied *Pœcilasma* is doubtfully represented in the newer Tertiaries.

CHAPTER XXIX.

CRUSTACEA—continued.

Sub-Class II.—Entomostraca.

Sub-class II. Entomostraca (*Gnathopoda*, Woodward). — The division of the Entomostracous Crustaceans includes a large number of comparatively simple types, in which the limbs and segments are usually indefinite in number, the former either fewer or more than fourteen; and the character of the appendages is very varied. The limbs are principally developed in the cephalic region, and their bases generally act as jaws. The characteristic larval form is that of a "nauplius." The orders of the *Eurypterida* and *Xiphosura* (with the probable addition of the *Trilobita*), here placed among the *Entomostraca*, are grouped together by Professor Claus in a special section, which he terms *Gigantostraca*, and which he regards as probably related to the *Arachnida*.

The *Entomostraca* are divided into three great divisions, or "legions," the *Lophyropoda*, *Branchiopoda*, and *Merostomata*.

Division A. Lophyropoda.

The members of this division possess few branchiæ, and these are attached to the appendages of the mouth. The feet are few in number, and mainly subserve locomotion; the carapace is in the form either of a shield protecting the cephalothorax, or of a bivalve shell enclosing the entire body. The mouth is mostly not suctorial, but is furnished with organs of mastication.

This division comprises the two orders *Ostracoda* and *Copepoda*.

Order I. Ostracoda.—*Small Crustaceans having the entire body enclosed in a shell or carapace, which is composed of two valves united along the back by a membrane. The valves are capable of being closed by an adductor muscle, the insertion of which in the interior of each*

valve is marked by a tubercle, pit, or group of spots, or by both spots and a pit. There are seven pairs of appendages, of which the first two are antennæ, and the posterior appendages are adapted for creeping or swimming.

The *Ostracoda* are all small Crustaceans in which the body is enclosed within a bean-shaped or mussel-shaped shell, composed of two valves united along the back by an elastic ligament (fig. 360, B). The animal can open the valves of the shell along their ventral margin, and can protrude the appendages and the caudal extremity of the abdomen. The first two pairs of appendages are antennules

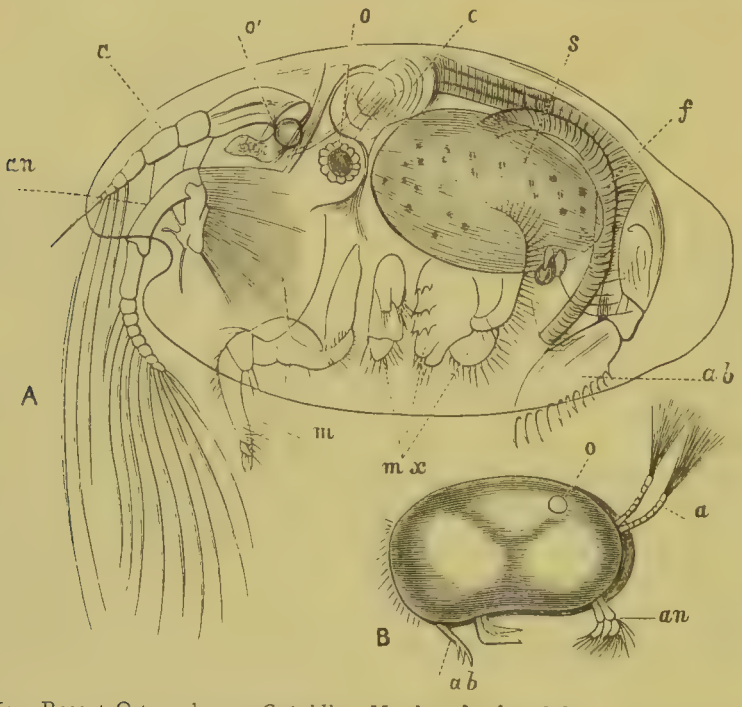


Fig. 360.—Recent Ostracoda. A, *Cypridina Messinensis*, viewed from the side, and greatly enlarged, one-half of the shell being removed. B, *Cypris fusca*, viewed from the side, and less highly magnified, the shell-valves being retained, but slightly displaced. *a*, Antennules; *an*, Antennæ; *o*, Eye; *o'*, Ocellus; *c*, Heart; *s*, Stomach; *f*, Whip-like appendage for the retention of the brood; *ab*, Extremity of the abdomen; *m*, Mandibular appendage; *mx*, The first, second, and third maxillæ.

and antennæ (fig. 360, A), which can be used as locomotive limbs. These are followed by a pair of mandibles, succeeded by a pair of maxillæ; and the next two pairs of appendages may be either jaws or legs. The sixth and seventh pairs of appendages are leg-like, and variously formed in different cases. A median eye, or two lateral eyes are present. Branchial plates are attached to some of the jaws, and a distinct heart may be present (*Cypridina*) or absent (*Cypris* and *Cythere*). The young forms are usually "nauplii," but

there may be no metamorphosis. Parthenogenesis is a not uncommon phenomenon in the Ostracodes.

The *Ostracoda*, often called "Water-fleas," are represented by very numerous forms both in fresh water and in the sea. The commonest fresh-water types are the little *Cyprides* (fig. 360, B). The marine Ostracodes (*Cythere*, *Cypridina*, &c.), are mostly shallow-water forms, and are of small size; but there are deep-sea types which attain comparatively gigantic dimensions (nearly an inch in length). Numerous fossil forms of the Ostracodes are known, their remains occurring in all formations, from the Cambrian onward.

It is only the carapace-valves of the Ostracode Crustaceans that are preserved in the fossil condition, with the rarest exceptions; and the general form of the carapace is often very similar in different genera. Hence the palæontologist has to rely, in the discrimination of these minute fossils, upon small variations of shape, differences in the thickness of the valves, the characters of the edges of the valves, or the manner in which they are hinged to one another, or, lastly, the surface-ornamentation. Besides the difficulty attaching to the study of the fossil *Ostracoda* from their small size and general similarity of appearance, it is often by no means easy to distinguish between the cephalic and the posterior extremity of the body. When not alike, the most contracted extremity is to be regarded as the head, and the widest as the hinder end of the carapace. The former, as a rule, carries grooves or tubercles, when such structures are present at all. The tubercles of the test, where developed, appear to represent the eye; and the grooves and intervening lobes, which are found in many forms, have been aptly compared by Barrande to the furrows and lobes of the glabella of Trilobites. There are many types, however, in which there are no conspicuous external markings, and in which the two ends of the carapace are similar. The Mesozoic and Tertiary *Ostracoda* are very small, and the same is true of a large number of Palæozoic species; but among the latter we find some comparatively large types, which, like *Leperditia Hisingeri*, may reach fifteen millimetres or more in length. As a rule, also, the Palæozoic *Ostracoda* are plain, or are simply striated or granular; whereas the Mesozoic and Tertiary forms are commonly ornamented with projecting tubercles, or in various other ways. As regards their general distribution in time, the *Ostracoda* certainly commence in the Upper Cambrian, and are even doubtfully represented in the lower division of this formation. They existed under many and varied types in the Ordovician and Silurian, and are abundant in all the succeeding formations, till the Recent period is reached. As matter of course, the remains of this group of Crustaceans with which we have chiefly to do, are principally those of the *marine* members of the order, and this is especially

true as regards the Palæozoic species. In later deposits, however, the occurrence of Ostracodes of types now found in fresh or brackish water is by no means uncommon.

The total number of fossil *Ostracoda* is very large, the difficulties attending their study, for reasons already stated, are quite exceptionally great; and it is impossible, in many cases, for the student to discriminate species, or, often, even genera, unless he should have made the group a subject of special investigation. Here, therefore, no attempt will be made to give even the briefest analysis of the families or genera of the order; but it may be well to shortly characterise some of the common or more remarkable types, with special reference to the Palæozoic forms, with which, upon many grounds, it is desirable that the student should have some acquaintance.

Among the Palæozoic Ostracodes, the first group that may be noticed is that of which *Leperditia* (fig. 361, C and D) is the type (*Leperditidæ*). In this genus the two valves are unequal in size, smooth, nearly oblong, bean-shaped, with the posterior end wider than the anterior. There is a small tubercular eye-spot, placed on the head, near the hinge, and underneath and behind this is a slightly inflated area, corresponding with an excavation of the shell interiorly, and exhibiting reticulated or areolar muscular markings. Behind the eye-spot is generally a vertical groove, which begins at the dorsal margin, and extends a short way across the valves. The genus ranges from the Ordovician to the Carboniferous. *Isochilina* (fig. 361, B) nearly resembles the preceding, but the valves are equal. It is not uncommon in the Ordovician rocks.

The genus *Primitia* (fig. 361, E–G) comprises another group of Palæozoic Ostracodes, which is essentially characteristic of the Cambrian, Ordovician, and Silurian deposits, though apparently also represented in the Carboniferous. In this genus the carapace is equivalve, convex, and oblong in shape, indented with a vertical dorsal groove of variable depth. Related to *Primitia* is the familiar genus *Beyrichia* (fig. 361, H and I), which is confined to the Cambrian, Ordovician, and Silurian rocks, and which sometimes is present in such vast numbers as to give rise, by the accumulation of the carapace-valves, to regular bands of limestone. The carapace of *Beyrichia* is more particularly distinguished by the possession of two or three transverse grooves, which start at the hinge, and pass partially or wholly across the valves. In the curious *Beyrichia* (?) *oculifera*, the eye-spot forms a prominent and faceted tubercle, unlike that of any other Ostracode (fig. 361, I). Two other members of the ancient family of the *Leperditidæ* may be just mentioned—namely, *Kirkbya* and *Moorea*, of which the former ranges from the Silurian to the Permian, while the latter is principally Carboniferous, and is doubtfully represented in the Jurassic rocks.

Another great group of the *Ostracoda* is that of the *Cypridinidæ*, in which the carapace is compact, smooth, or punctate, or striated, with a deep incision in the anterior margin for the exit of the larger

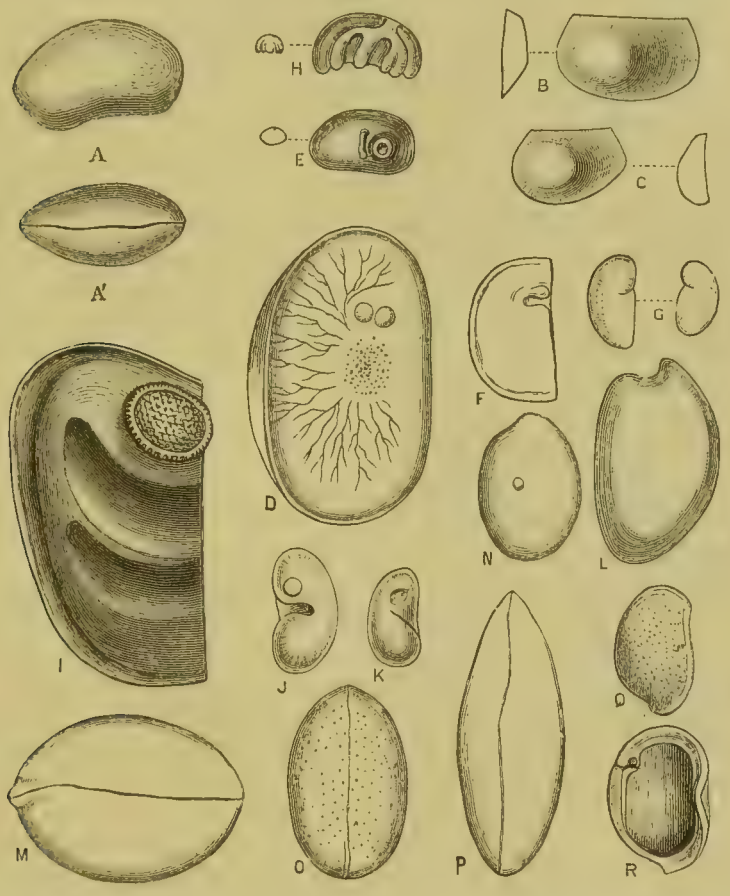


Fig. 361.—Types of Ostracoda. A, The test of *Cypris faba*, from the Miocene, viewed sideways, and enlarged fifteen times; A', The same, viewed from the dorsal margin; B, *Isochilina Ottawa*, enlarged four times (left valve and ventral view)—Ordovician; C, *Leperditia Josephana*, of the natural size (right valve and anterior view)—Ordovician; D, *Leperditia solitaria*, enlarged, showing the eye-spot and muscular impression—Silurian; E, *Primitia* sp.—Silurian; F, *Primitia strangulata*, Ordovician, enlarged; G, Right and left valves of *Primitia tarda*—Silurian; H, *Beyrichia complicata*—Ordovician; I, *Beyrichia* (?) *oculifera*, showing the elevated eye-spot, greatly enlarged—Ordovician; J, *Entomis tuberosa*, Jones (=*E. pelagica*, Barr.), right valve, enlarged twice—Silurian; K, *Entomis impendens*, enlarged—Silurian; L, *Cypridina Wrightiana*, left valve, enlarged four times—Carboniferous; M, Dorsal view of a small example of *Entomoconchus Scouleri*, enlarged four times—Carboniferous; N, Left valve of *Polycope simplex*, enlarged eight times—Carboniferous; O, *Cypris Browniana*, viewed dorsally, enlarged twenty-five times—Pleistocene; P, *Candona candida*, viewed ventrally, and similarly enlarged—Post-Tertiary and Recent; Q, *Cythere convexa*, right valve, similarly enlarged—Pliocene and Recent; R, Interior of left valve of the same. (After Barrande, Rupert Jones, M'Coy, Hall, and G. S. Brady.)

antennæ. Numerous living forms of the *Cypridinidæ* are known, and the family is represented in past time principally by the three generic types, *Cypridina*, *Entomis*, and *Entomoconchus*, the last two

of these being entirely extinct. In *Cypridina* (fig. 361, L) the carapace is produced in front into a beak-like projection, below which is a hollow or notch facing the ventral margin. Many of the so-called *Cypridinæ* of the older Palæozoic rocks are now known to be referable to other types, but the genus is well represented in the Carboniferous, and exists at the present day. *Entomis* (fig. 361, J and K) ranges from the Ordovician to the Carboniferous, but attains its maximum in the Devonian rocks. The carapace in this genus resembles that of some of the *Leperditidæ* in having a dorsal groove, indenting the valves transversely, and sometimes reaching the ventral margin, and having a rounded tubercle placed at or near its lower end. One species of this genus (*Entomis serratostriata*), formerly known as a *Cypridina*, is so abundant in certain of the Devonian strata of Germany as to have gained for these the name of "Cypridinen-Schiefer." *Entomoconchus* (fig. 361, M), again, is a large form, with a thick and globose carapace, having a much less developed notch in front than in *Cypridina*. It is confined to the Carboniferous rocks. Among other Carboniferous *Cypridinidæ* may be mentioned the genera *Cyprella*, *Cypridella*, *Cypridellina*, *Sulcuna*, and *Rhombina*, all of which are characteristic of the Carboniferous rocks.

Another group of the Ostracodes (*Polycopidæ*) is that characterised by the genus *Polycope* (fig. 361, N), in which the carapace-valves are subequal and thin, not markedly notched in front, and having no beak. Though represented by living species, the only undoubted members of this genus which have been detected in a fossil state are from the Devonian and Carboniferous rocks.

The genus *Cytherella* is the type of another group (*Cytherellidæ*), in which the valves are very thick and calcareous, and are not notched in front. In *Cytherella* itself the right valve is much larger than the left, overlapping the latter throughout the whole circumference, and "presenting round the entire inner margin a distinct groove, into which the valve of the opposite side is received" (G. S. Brady). The genus ranges from the Carboniferous to the present day; and we may provisionally place with it the *Cytherellina* and *Æchmina* of the Silurian.

Lastly, we have the great group of Ostracodes represented by the families of the *Cypridæ* and *Cytheridæ*, "including all the fresh-water and a vast majority of the marine *Ostracoda*, and embracing all the forms classed by the earlier writers under the two great genera *Cypris* and *Cythere*" (G. S. Brady).

In the *Cypridæ*, as typified by *Cypris* itself (fig. 361, A and O), the valves are thin and smooth, and more or less sinuate below. Most of the *Cypridæ* are inhabitants of fresh water, and the fossil forms are principally found in lacustrine or fluviatile deposits, often

occurring in astonishing abundance. A few forms (such as *Bairdia* and *Pontocypris*) are marine in habit. The family of the *Cypridæ* seems to have attained its maximum at the present day, but is represented in deposits as old as the Carboniferous by forms which are believed to be referable to the living genera *Candona* and *Bairdia*. Specimens of the Carboniferous genus *Palæocypris* have been found, showing the eye, the antennæ, and the jointed limbs, of which there are two pairs behind the mandibles, the last pair being strongly incurved.

In the family of the *Cytheridæ*, lastly, the shell is minute, thick, inequivalve, and generally elongated or reniform in shape. The dorsal margin of the carapace has two denticles in the right valve fitting into corresponding sockets in the left valve. The surface is smooth, or is variously ornamented with tubercles or spines. The genera of *Cytheridæ* are mainly Recent and Tertiary; but the genus *Cythere* ranges from the Silurian to the present day, and there are various Secondary types belonging to the genera *Cythereis* and *Cytheridea*.

Order II. Copepoda.—*Small Crustaceans having bifid natatory feet, and the head and thorax usually covered with a carapace. Two caudal locomotive appendages are often present; but the abdomen does not carry limbs. Segmentation is distinct in the free forms; but it is more or less lost in the females of the parasitic types.*

The order of the *Copepoda* comprises numerous small Crustaceans, which inhabit both fresh and salt water, many types being parasitic in habit. No certain examples of the Copepods have hitherto been detected in the fossil condition.

Division B. Branchiopoda.

The Crustaceans included in this division have many branchiæ, and these are attached to the legs, which are often numerous, and are formed for swimming. In other cases the legs themselves are flattened out so as to form branchiæ. The body is either naked, or is protected by a carapace, which may enclose either the entire body, or the head and thorax only. The mouth is provided with organs of mastication.

The *Branchiopoda* comprise the *Cladocera*, the *Phyllopoda*, the *Phyllocarida*, and probably the *Trilobita*, though this last departs in many respects from the first three groups.

Order I. Cladocera.—The members of this order are *small Crustaceans, which have a distinct head, and have the whole of the remainder of the body enclosed within a bivalved carapace. The feet are few in number (usually four, five, or six pairs), and are mostly respiratory, carrying the branchiæ. Two pairs of antennæ are*

present, the larger pair being of large size, branched, and acting as natatory organs.

The types of this order are mostly confined to fresh water, a few forms being found in brackish pools. No undoubted representatives of the *Cladocera* have been hitherto detected in the fossil state, though a few small fossil types have been referred to this order.

Order II. Phyllopoda.—*Crustacea, mostly of small size, generally having the front part of the body protected by a shield-like carapace, or sometimes having the body enclosed in a bivalve shell. The feet are usually numerous, and more or fewer of them are leaf-like in form, and act as respiratory organs.*

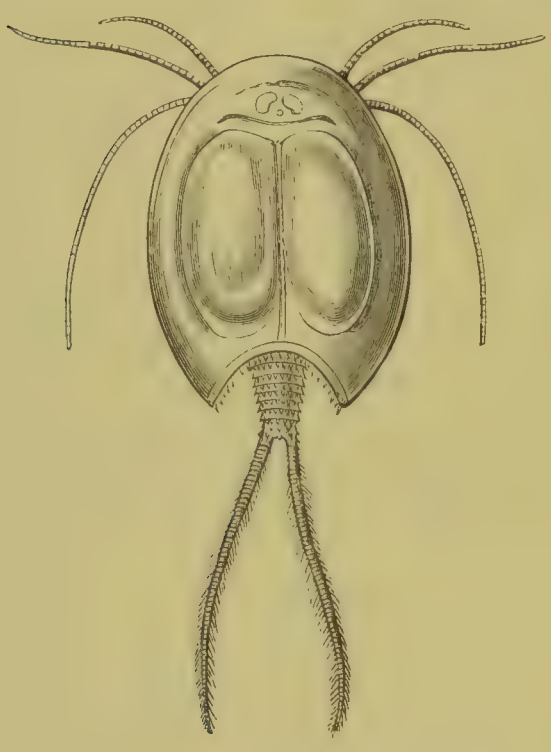


Fig. 362.—*Apus cancriformis*, a recent Phyllopod, viewed from above, and enlarged.

The living types of the Phyllopods (*Apus*, fig. 362, *Branchipus*, *Limnadia*, *Estheria*, &c.) are mostly inhabitants of fresh water, but species of *Estheria* are found in brackish water, and the *Artemiæ* live in salt lakes, or in the brine-pans of salt-works. As a type of the Phyllopods the recent genus *Apus* (fig. 362) may be taken, in which the anterior part of the body is covered with an oval carapace, carrying a pair of compound eyes upon its upper surface in front. The under surface carries sixty pairs of feet, of which the first is divided into three slender whip-like branches on each side, while the others are of the genuine "phyllopodous" type, being leaf-like in form, and acting as breathing-organs in function.

If the recent genus *Nebalia* and its numerous fossil allies are removed to form the order *Phyllocarida*, then the number of known fossil Phyllopods is comparatively small. By far the most important type, from a palæontological point of view, is the genus *Estheria* (fig. 363, A), which is nearly related to the living *Limnadia*, and

which in some respects constitutes a connecting-link between the Phyllopods and the Ostracodes. The body in *Estheria* is enclosed in a bivalve carapace, and the feet are foliaceous. The valves of the carapace have a well-marked beak or "umbo," and are hinged to one another along a dorsal line. From these circumstances, and from their being marked with numerous concentric lines of growth, the carapace-valves of *Estheria* very closely resemble the shells of certain Bivalve Molluscs (*Posidonia* and *Posidonomya*), for which they have often been mistaken. The valves are usually sub-triangular, ovate, or sub-quadrate in form, and they possess a horny texture.

The living *Estheriæ* are, without exception, inhabitants of fresh, or, rarely, brackish water; and no one of the recent twenty-four species has been detected in the sea. This would afford a strong

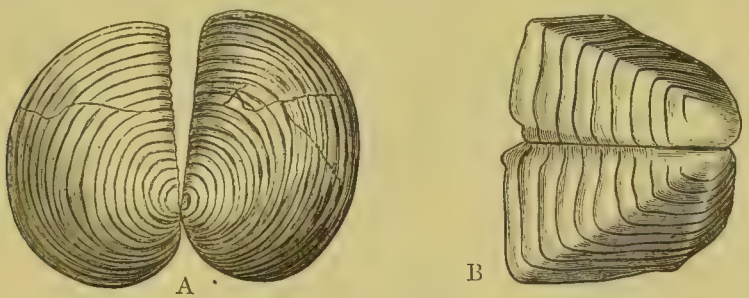


Fig. 363.—A, Carapace of *Estheria ovata*, magnified six diameters—Trias; B, Carapace of *Leaia Leidyi*, magnified five diameters—Lower Carboniferous. (After Rupert Jones.)

presumption that the deposits in which *Estheriæ* occur were laid down in fresh or brackish water; but such fossils not uncommonly occur in conjunction with undoubted marine remains. They appear, on the whole, to occur most frequently in those accumulations that "have been decidedly the result of brackish-water inundations, and of more permanent lagoons" (Jones). Fossil *Estheriæ* occur in the Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, and some Tertiary deposits; but they appear to have attained their maximum development towards the close of the Triassic period. The allied genus *Schizodiscus* is Devonian, and *Estheriella* is found in the Trias.

The genus *Leaia* (fig. 363, B) is very nearly allied to *Estheria*, and comprises small Bivalved Crustaceans, with "dark, horny, sub-quadrate valves, obliquely ridged from umbo to angles, and ornamented with distinct lines of growth parallel with the border" (Jones). *Leaia* is a very widely distributed genus, but all the known species belong to either the Carboniferous or Permian rocks. It has been suggested, however, that the obscure Ordovician genera *Myocaris* and *Ribeiria* are allied to *Leaia*.

Lastly, we may notice that a Phyllopod nearly allied to the living fresh-water genus *Branchipus* has been detected by Dr Henry Woodward in the Eocene formation, and has been described by him under the name *Branchipodites vectensis*. The much older *Branchipusites* (rightly *Branchipodites*) *anthracinus*, of the Coal-measures, has been supposed to have similar relationships, but it does not appear to be truly a Phyllopod.

Order III. Phyllocarida.—This order was founded by Packard to include the recent genus *Nebalia* along with certain extinct types of the *Crustacea*, which in some respects form a connecting-link between the Phyllopods and the Malacostracous group of the Schizopods, though they appear to be properly referable to the *Branchiopoda*. The principal living form of the *Phyllocarida* is *Nebalia*, which must be regarded as constituting with its immediate allies the family of the *Nebaliadæ*, and which must be taken as giving the essential characters of the order. In the genus *Nebalia* (fig. 364), the anterior part of the body is covered with a folded, but unhinged, cephalothoracic shield or carapace, which is connected with the body in its cephalic part only, and extends down the sides so as to enclose the mouth organs and the greater part of the other appendages. The valves of the carapace are not separated along the back, but are moved by an adductor muscle. In front of the carapace, and movably articulated to it, is a rostral plate; and there are also two compound stalked eyes, the cornea of which is not faceted. Two pairs of antennæ are present. The segments of the thorax, though enclosed by the carapace, are free, and carry eight pairs of foliaceous feet, which are of the "phyllopodous" type, and officiate as branchiæ. The abdomen is composed of free rings, the first four somites of this region carrying as many pairs of biramose legs, while there are also two pairs of rudimentary caudal limbs. No telson is present in *Nebalia* and its allies, but there is a well-developed telson in the *Ceratiocaridæ*. There is no metamorphosis in development.

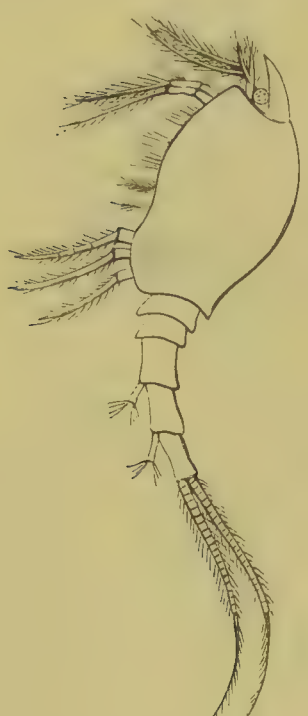


Fig. 364.—*Nebalia Herbstii*, enlarged about three times. Recent.

The living types of the *Phyllocarida* belong to the genus *Nebalia* and the closely related *Nebaliopsis* and *Paranebalia*, and are all small

Crustaceans, which are exclusively marine in habit. The recent forms constitute a special division of the order (*Nebaliadæ*), distinguished, among other characters, by the want of a telson; and they are not known to be directly represented in the fossil state. On the other hand, there are numerous fossil Crustaceans, chiefly of Palæozoic age, which appear to be properly referable to the *Phyllocarida*, and which may be regarded as constituting a special division of this order (*Ceratiocaridæ*), distinguished more particularly from the *Nebaliadæ* by the presence of a well-developed telson. The earliest forms of this peculiar group of "Pod-shrimps," as they have been termed, appear in the Cambrian period, while the group

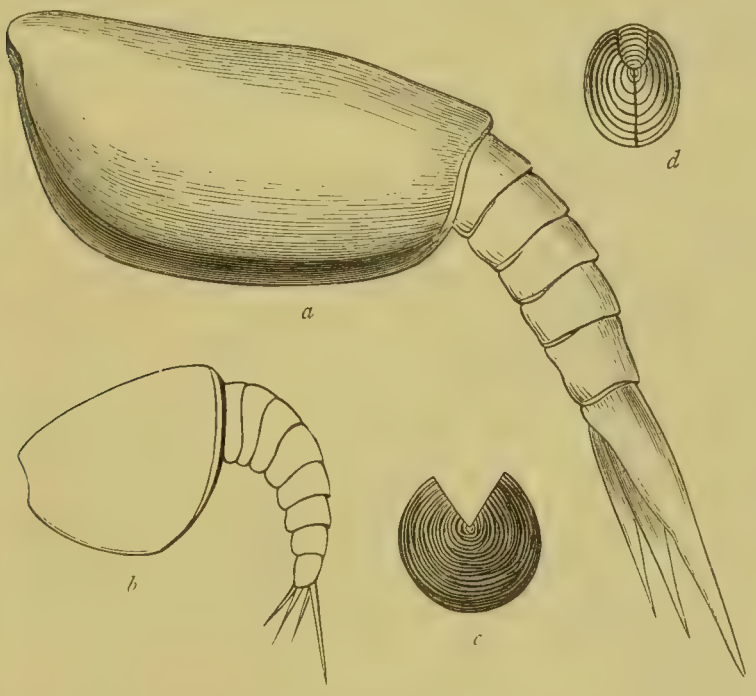


Fig. 365.—Palæozoic Phyllocarida. *a*, *Ceratiocaris papilio*—Silurian (Salter); *b*, *Hymenocaris vermicauda*—Upper Cambrian (Salter); *c*, *Discinocaris Browniana*, without the "rostrum"—Ordovician (Original); *d*, *Peltocaris aptychoides*—Ordovician (Woodward).

attains its maximum development in the Silurian, and underwent almost total extinction subsequent to the close of the Carboniferous period. The number of genera included in the family of the *Ceratiocaridæ* is very large, and many of these are only imperfectly understood. It will therefore be sufficient here to allude briefly to some of the more important and better known types.

As the type of this group may be taken the genus *Ceratiocaris* itself (fig. 365, *a*) in which the anterior portion of the body is enclosed in an elongated or pod-like carapace, composed of two oval

valves, contracted in front and with an abrupt posterior truncation. The carapace-valves are united along the back by a median line of attachment, and are commonly marked with fine linear striæ, while a lanceolate rostrum is developed in front. There were fourteen or more body-rings, of which the last five or six were free, some or all of these supporting lamellar appendages which seem to have been branchial in function. At the hinder end of the body is a powerful pointed telson, with two smaller lateral spines. The thoracic limbs are unknown, but toothed jaws have been in some instances recognised, either detached or in connection with the body of their former possessor. The oldest species of *Ceratiocaris* appear in the Ordovician rocks, but the genus attained its maximum in the Silurian period, and the last known forms occur in the Lower Carboniferous deposits. Some of the species attained to a great size, *C. Ludensis* growing to a length of two feet.

In the Cambrian rocks is found the allied genus *Hymenocaris* (fig. 365, *b*), in which the large sub-triangular carapace is not bivalved but is simply folded. There are generally nine free abdominal segments, the hinder termination of the body being adorned with three pairs of unequal spines. The Cambrian rocks of North America have yielded the remains of the related genus *Protocaris*, which differs from *Hymenocaris* principally in the possession of thirty narrow abdominal rings, and in the fact that there is a large telson ending in two terminal spines. Of the same general type as the preceding is the Ordovician genus *Caryocaris*, which agrees with *Ceratiocaris* in the fact that the carapace is bivalved, instead of being simply folded. The carapace is pod-like in form, and truncated behind, and the abdomen terminates in three spines. The researches of Novák have, further, shown that the singular Crustaceans described by Barrande from the Silurian rocks of Bohemia under the names of *Aristozoë*, *Callozoë* and *Orozoë*, and originally regarded by this observer as gigantic Ostracodes, are really referable to the *Ceratiocaridæ*. The carapace of *Aristozoë* (fig. 366) reaches three inches in length, and is composed of two valves united along a straight dorsal margin, its general shape being oval, with a pointed anterior and rounded posterior margin, and its front portion carrying prominent rounded tubercles. Novák has shown that the fossil described under the name of *Bactropus* is really a portion of the abdomen of *Aristozoë*, and that the so-called *Ceratiocaris debilis* is the telson of the same genus.

Of the later forms of the *Ceratiocaridæ*, the Devonian rocks of North America have yielded the remains of the curious genus *Echinocaris*, in which there is an ovoid folded carapace, adorned anteriorly with tubercles, and apparently without a rostrum. There are seven free abdominal segments, and a strong trifurcate telson.

Lastly, in the Carboniferous and Devonian genus *Dithyrocaris* (fig. 367), there is a broad carapace composed of two semi-oval valves ridged along the back in the middle line and laterally, and there is only one free body-ring. The rostrum is unknown, but there is a powerful trifurcate telson.

Another remarkable series of the *Phyllocarida* comprises forms with a thin, concentrically striated carapace, which may be simple, or may be divided into two halves and sutured along the back, and which is commonly notched in front for the reception of a triangular movable "rostrum." A number of curious, and in some cases problematical, fossils, the oldest of which are found in the Ordovician, while the last appear in the Trias, have been included in this group, and only a few of the more important can be noticed here. A typical genus of this group is the *Peltocaris* of the Ordovician rocks (fig. 365, *d*), in which the carapace is approximately circular,



Fig. 366.—Carapace of *Aristozoë memoranda*, from the Silurian rocks of Bohemia, of the natural size, viewed sideways, with the dorsal margin to the left. (After Barrande.)

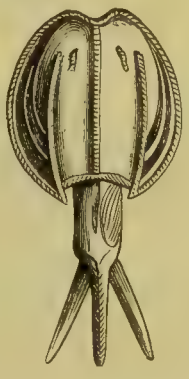


Fig. 367.—*Dithyrocaris Scouleri*, viewed from above, reduced slightly in size. Carboniferous Limestone. (After M'Coy.)

and consists of two valves of a semicircular form, which are united along the back by a straight dorsal suture, and which are deeply notched in front for the reception of a movable parabolic plate or "rostrum." The Ordovician and Silurian genus *Aptychopsis* is very similar in general characters to *Peltocaris*, but the rostrum is triangular in form. In the Silurian genus *Pterocaris* the same general type of structure is retained, but the valves are only united for a short space anteriorly, while they diverge behind, so as to form a wide posterior notch. On the other hand, in the remarkable Silurian genus *Discinocaris* (fig. 365, *c*), the concentrically striated carapace is circular in form, and shows no median line of suture on its dorsal surface, while there is a deep triangular notch in front for the reception of the rostrum. One species of this genus attains a diameter

of seven inches across the carapace. Various Devonian fossils have been placed, under special generic names, in the immediate neighbourhood of *Discinocaris*, and the Triassic genus *Aspidocaris* is also regarded as closely allied to this genus.

Order IV. Trilobita.—The Trilobites are Palæozoic Crustaceans in which *the body is more or less distinctly trilobed, and the head, thorax, and abdomen are distinct. The head is covered with a cephalic shield, which usually bears a pair of compound sessile eyes, ocelli being apparently never developed. The somites of the thorax are*

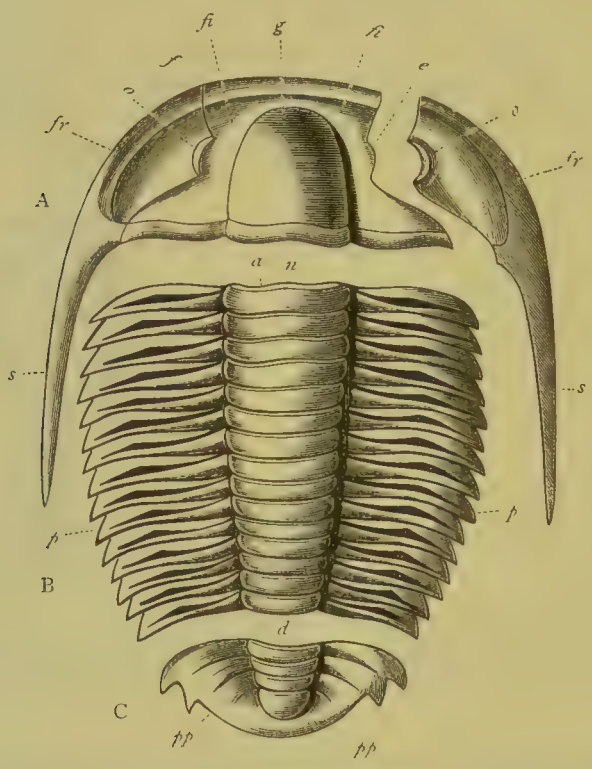


Fig. 368.—The skeleton of a Trilobite (*Angelina Sedgwickii*), partially dissected. A, Head-shield; B, Movable rings of the thorax; C, Tail or abdomen. *g*, Glabella, in this species without furrows; *fi*, Fixed cheeks; *e*, Eye-lobe; *o*, Eye; *f*, Facial suture; *fr*, Free cheeks; *s*, Head-spines; *p*, Pleuræ; *pp*, Anchylosed pleuræ of pygidium.

movable upon one another, and carry jointed legs to which branchiæ were attached. The abdominal segments are fused to form a caudal shield, and support below jointed appendages similar to those of the thorax. A well-developed upper lip ("*hypostome*") *is present, and some of the cephalic appendages are modified to act as mouth-organs.*

As regards the general structure of the *Trilobita*, the body was protected by a well-developed calcareous shell or "crust" which covered the whole dorsal surface of the body, and which usually

exhibits more or less markedly a division into three longitudinal lobes (fig. 368), from which the name of the order is derived. In some cases, however, as in the genera *Homalonotus* and *Illænus*, this trilobation is only obscurely marked. Within the limits of the same species, Barrande has observed that the individuals may sometimes present themselves under two forms, one broad and the other long, and he regards the broad forms as the females, and the long forms as the males, of the species.

The crust exhibits a well-marked division into three regions, which are commonly found detached and separate from one another. These three regions are—1, a cephalic shield; 2, a variable number of movable "body-rings" or thoracic segments; and 3, a caudal shield or "pygidium."

The cephalic shield or buckler (fig. 368) is generally more or less semicircular in shape, and is composed of a central and two lateral pieces, of which the two latter may or may not be united in front of the former. The central portion of the cephalic shield is usually elevated above the remainder. It is termed the "glabella" (fig. 368, *g*), and it protected the region of the stomach. The form of the glabella varies a good deal. Usually it is widest in front (fig. 369), but its width may be nearly uniform, or it may be widest posteriorly and contracted in front, as in *Calymene*. The glabella is bounded at the sides by two grooves, which are known as the "axal furrows," and is marked off behind by a third groove, which is termed the "neck-furrow." The surface of the glabella may be quite smooth, but it is ordinarily divided into "lobes" by "grooves," which originate in the axal furrows, and pass inwards towards the middle line (fig. 369). These furrows mark the position of the segments which compose the glabella, and they are sometimes continuous from side to side. Usually there are three pairs of these furrows, a lower or basal, a middle or ocular, and an upper or frontal furrow; but there may be an additional pair of furrows in front of these. In some cases, as in *Illænus* (fig. 374), the glabella is very indistinctly marked off from the rest of the shield.

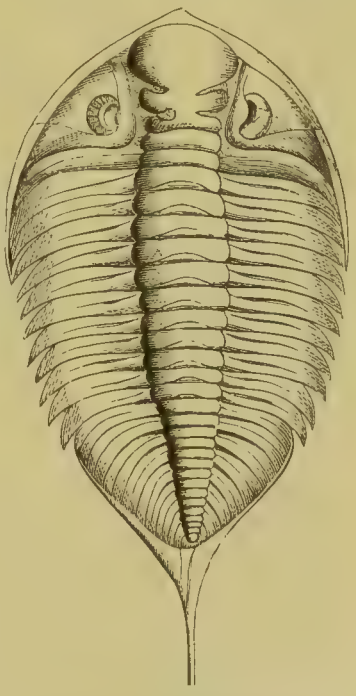


Fig. 369.—*Phacops* (*Dalmanites*) *caudata*. Upper Silurian.

The grooves of the glabella probably mark off so many *segments*, to which organs of prehension and mastication were attached inferiorly, and they are marked internally by corresponding ridges, to which muscles must have been attached. Sometimes (*Illænus*, *Ellipsocephalus*, *Encrinurus*, &c.) they are obsolete, as also occurs in particular species of other genera (*Trinucleus* and *Æglina*). Typically, three pairs of grooves are present, but some species of *Phacops* have four, and so have other types.

In certain Trilobites there are found two pores, or, in other cases, funnel-shaped depressions, one on each side of the glabella, in the axal furrow which separates this region from the cheeks. M'Coy thought that these "cephalic pores" might have been the points of origin of a pair of antennæ. It is certain, however, that this cannot be the true explanation of these structures; and they may be perhaps accounted for as marking the point of origin of deep internal processes of the exoskeleton to which muscles were attached, while it has also been suggested that they may indicate the position of a pair of "ocelli."

At each side of the glabella, and continuous with it, is a small semicircular area, which is termed the "fixed cheek" (fig. 368, *fi*). The glabella, with the "fixed cheeks," is separated from the lateral portions of the cephalic shield, termed the "movable" or "free" cheeks, by a peculiar suture or line of division, which is known as the "facial suture" (fig. 368, *f*). No such line of division is known to exist in any recent Crustacean; but there is a faint indication of it in *Limulus*, and some doubtful traces of it in certain other forms. The course taken by the facial sutures differs in different cases, and causes an important difference in the structure of the cephalic shield. In some cases (*Asaphus*, *Phacops*, *Homalonotus*, &c.) the facial sutures, starting from the posterior margins of the buckler, skirt the fixed cheeks, and join one another in front of the glabella. In these cases it is obvious that the free cheeks form a single piece, so that the entire shield consists of but two portions—1, the glabella and fixed cheeks; and 2, the amalgamated free cheeks. In other cases (*Paradoxides*, *Illænus*, *Proetus*, &c.), the facial sutures, instead of joining in front of the glabella, are continued forward, till they cut the anterior margin of the shield separately. In these cases the free cheeks are discontinuous, and the cephalic shield consists of three portions. In a few genera (as in *Trinucleus*, *Microdiscus*, and *Agnostus*) the facial sutures are absent, in which case the free and fixed cheeks are fused with one another.

The posterior angles ("genal angles") of the free cheeks are very commonly prolonged into longer or shorter spines, and the free cheeks also bear the eyes. The eyes are compound, and consist of an aggregation of facets, covered by a thin cornea. They are generally crescentic or reniform in shape, and are invariably *sessile*, in the sense that they are never supported upon movable stalks. In some cases, however, they are carried upon longer or shorter prominences. The eyes differ much in size, and they are wanting in a

few forms, such as *Agnostus*, *Ampyx*, some of the *Trinuclei*, and certain forms of *Conocephalus*. Though facets are usually easily detected in such as have eyes of any size, there are some (*Bronteus*, *Arethusina*, *Proetus*, &c.) in which the eyes are smooth. In any case, the number of lenses varies greatly, there being as few as fourteen facets, or as many as fifteen thousand in each eye in different types (Barrande).

Behind the cephalic shield comes the thorax, composed of a variable number of segments which are not soldered together, but are capable of more or less movement upon each other. The amount of movement thus allowed varies, but in several genera (*e.g.*, *Calymene* and *Illænus*) it was sufficiently great to allow of the animal completely rolling itself up after the manner of a hedgehog. The number of body-rings or segments in the thorax varies from no more than two (*Agnostus*) to as many as twenty-six (*Harpes ungula*), or twenty-nine. Ordinarily the thorax (fig. 373) is strongly trilobed, and each body-ring exhibits the same trilobation, being composed of



Fig. 370.—*Bronteus lunatus.*

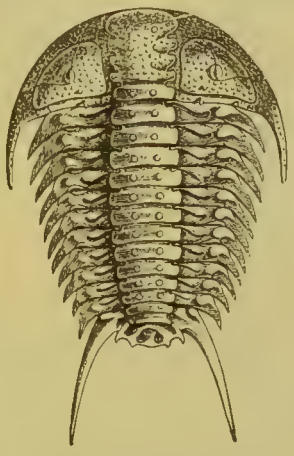


Fig. 371.—*Cheirurus pleurexanthemus.*



Fig. 372.—*Calymene Blumenbachii.*

a central, more or less convex portion, called the "axis," and of two flatter side-lobes, termed the "pleuræ." The pleuræ are in one piece with the axis, but are separated from it by a more or less pronounced groove, the "axal furrow." In one type of pleuræ, each of these structures carries a deep longitudinal groove or sulcus upon its upper surface (as in *Asaphus*, *Ogygia*, *Phacops*, *Calymene*, &c.) In another type, on the other hand (as in *Cheirurus*, *Bronteus*, *Acidaspis*, &c.), the place of the sulcus is taken by a similarly situated oblique *ridge*. The pleuræ are always bent downwards towards their ends, and also commonly bent backwards as well, the point where the backward curvature begins being the "fulcrum" of Salter. In the Trilobites

with grooved pleuræ, more especially, the pleuræ imbricate and overlap; and the "fulcrum" of each is often bevelled off, so as to form a facet upon which the pleura immediately in front plays, thus allowing the animal to *roll up*. In the state of complete enrolment, the under surface of the pygidium is closely applied to the corresponding surface of the head-shield, thus entirely concealing the ventral aspect of the animal. Some forms (such as *Homalonotus*, *Lichas*, *Triarthrus*, *Olenus*, *Paradoxides*, *Æglina*, &c.) are not known to have been endowed with the power of rolling up. Though the trilobation of the thorax is usually very well marked (figs. 370-373), at other times the axis is very broad, and the axal furrows more or less inconspicuous. This is the case in *Illænus* (fig. 374), and to a less extent in *Homalonotus*.

The caudal shield or "pygidium"—commonly called the "tail"—is composed of a greater or less number of segments anchylosed

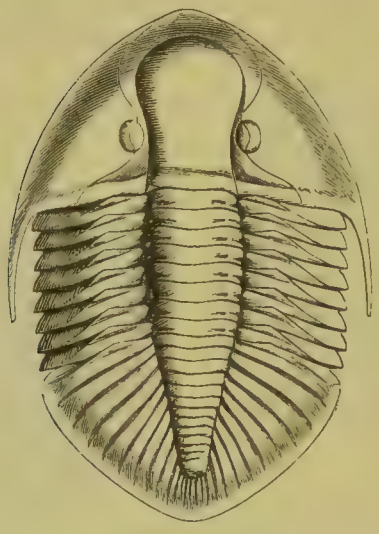


Fig. 373.—*Asaphus Canadensis* (Chapman). Ordovician.



Fig. 374.—*Illænus Barriensis* (Murchison). Silurian.

or amalgamated with one another. Commonly, the pygidium is trilobed (fig. 373), like the thorax, and consists of a central elevated "axis" and of a marginal "limb." The limb is separated from the axis by axal furrows, and usually exhibits on its surface the lines which indicate the component pleuræ, as well as the longitudinal furrows on the faces of these. The extremity of the pygidium is sometimes simply rounded, with an "entire" margin; but it may be prolonged into a shorter or longer spine or "mucro" (fig. 369), and the ends of the pleuræ may also be extended into spine-like projections (fig. 375). The number of rings in the tail varies from two (*Sao hirsuta*) to twenty-eight (species of *Amphion*).

With regard to the condition of the *under* surface of the Trilobites, the progress of our knowledge has been slow, and is still in some respects far from complete. Specimens showing the inferior surface are exceedingly rare, and until of late years the only structure which had been detected on this aspect of the animal was the



Fig. 375.—Glabella and pygidium of *Dikellocephalus magnificus*, Quebec group (Lower Ordovician). (After Billings.)

upper lip. The margin of the head-shield (as that of the pygidium also) is turned under in the form of a broader or narrower downward and inward inflection or "doublure" (fig. 377, *d*), and to the centre of this is attached the lip-plate or "hypostome." The form of this varies, but usually it is either an oval gibbous plate or it is broad and deeply forked behind (figs. 376, 377, *h*). Beside this lip-plate, in a specimen of *Asaphus platycephalus*, Dr Henry Woodward detected a jointed filament (fig. 376, *p*), apparently attached to a maxillary plate, and representing a "maxillary palpus." At a later period, Mr Billings described a specimen of *Asaphus platycephalus*, showing the under surface of the body, with a pair of apparently jointed appendages attached to each segment of the thorax; but the nature of these structures as ambulatory legs was not universally admitted. The correctness of the view held by Mr Billings as to the nature of the thoracic limbs in *Asaphus platycephalus* has, however, been completely established by a specimen of *Asaphus megistos*, from the Ordovician rocks of Ohio, which shows the under surface with its appen-

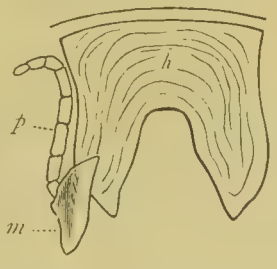


Fig. 376.—Buccal organs of *Asaphus platycephalus* (after Woodward). *h*, Hypostome; *p*, Palpus; *m*, Maxilla (?).

dages, and which has been described by Dr Mickleborough and Mr Walcott. In this remarkable specimen (fig. 377), all the segments of the thorax, as well as those of the pygidium, are provided with jointed limbs, while branchial filaments (*b*) are likewise present. Apart from the interesting specimens above noticed, the condition of the under surface of the Trilobites, with its appended structures, has been fully investigated by Mr Charles D. Walcott, whose researches have been carried on by the method of making thin transverse and longitudinal sections of rolled-up specimens. This able observer has shown that the visceral cavity of the Trilobites (fig. 378, *b*) was bounded inferiorly by a thin membrane, which was attached to the lower margin of the dorsal crust all round. This ventral membrane was supported by calcified arches, which in turn supported the appendages beneath. As to these latter, it is now established that there existed a row of articulated appendages on each side of the middle line below (fig. 379). In the genus *Calymene*, as will be seen from the accompanying illustrations, the thoracic appendages were in the form of slender, five-jointed legs, in which the terminal segment forms a pointed claw, and the basal segment carries a jointed appendage, regarded by Mr Walcott as homologous with the "epipodite" of many recent Crustaceans. On each side of the thoracic cavity there is, also, attached a row of bifid spiral appendages (fig. 378, *e*), of the nature of gills; and branchial appendages were probably attached to the bases of the

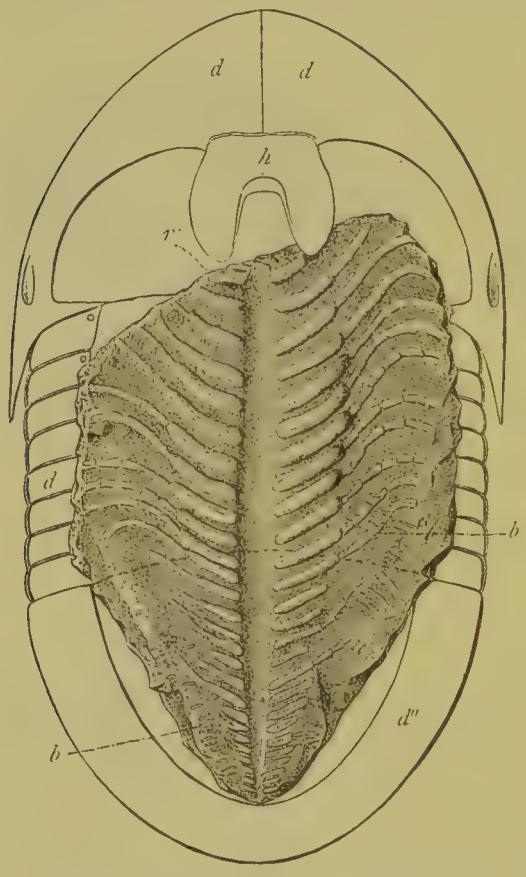


Fig. 377.—Under surface of the body of *Asaphus megistos*, from the Ordovician rocks of Ohio, with the missing parts restored in outline. *d*, and *d''*, Doublure or infolded margin of the cephalic shield, thorax, and pygidium respectively. All the rings of the thorax and tail carry jointed limbs, and branchial filaments (*b*) are also present. In front, the bases of the last pair of cephalic appendages (maxillipedes) is shown (*m*). *h*, The hypostome. (After Walcott.)

thoracic limbs as well. The abdominal or pygidial rings carried appendages also, a pair to each segment, but these do not appear to have differed in form from the thoracic limbs. With regard, finally, to the appendages of the head, the mouth is situated behind the hypostome, and is bounded by four pairs of jointed manducatory appendages, the basal joints of which are, partly or wholly, modified to act as jaws. The hindmost cephalic appendages (fig. 379, *b*) are larger than the anterior ones, and may be regarded as foot-jaws.

In connection with the exoskeleton of the Trilobites, a few words may be said as to the *minute* structure of the crust. Thin vertical sections (fig. 380, B) show that the crust is traversed by vertical canals or tubes of different sizes, the general tissue being finely

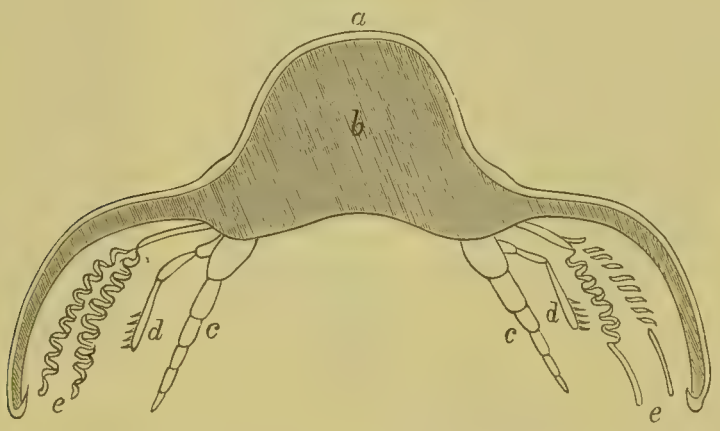


Fig. 378.—Transverse section of the thorax of *Calymene senaria*, partially restored (after C. D. Walcott). *a*, Dorsal crust; *b*, Visceral cavity, continued laterally to the pleural margins of the dorsal crust; *c*, Legs, restored; *d*, Epipodite; *e*, Spiral gills. Enlarged six times.

tubulated so as to resemble somewhat the dentine of teeth, and there being usually a system of comparatively large vertical tubes as well. Tangential sections (fig. 380, A and C) may only exhibit the openings of the larger set of tubes, or may show the minute and close-set apertures of the small tubuli as well. Where a large set of tubes is clearly developed, the minute structure of the crust is very similar to that of the shell of the recent *Limulus*; but the presence of these large tubes cannot be regarded as a distinctive feature, since similar canals are present in the shell of the Lobster, in parts at any rate.

With regard to the *development* of the Trilobites, the eggs have been noticed by both Barrande and Walcott. They are spheroidal or cylindroidal in shape, and mostly about a twenty-fifth to a fiftieth of an inch in diameter, and they seem to have been deposited in clusters. The larval condition of the Trilobites is only known in

certain cases, and it is possible that the young may often have been naked. This subject has been chiefly worked out by Barrande, who has shown that, so far as our present knowledge goes, the development of the Trilobites follows one or other of four principal lines. In one group of forms (*e.g.*, *Sao hirsuta*), the most minute larvæ observed possess a head-shield, but have no pygidium, while the thorax is either wanting or rudimentary. In another type (*Agnostus*), the larva has both the head-shield and pygidium in a developed condition, but the thorax is wanting. In a third, all the three regions of the body are present, but the thorax and pygidium are at first incomplete; and in a fourth group, though the thorax possesses the number of rings proper to the adult, the pygidium is imperfect.

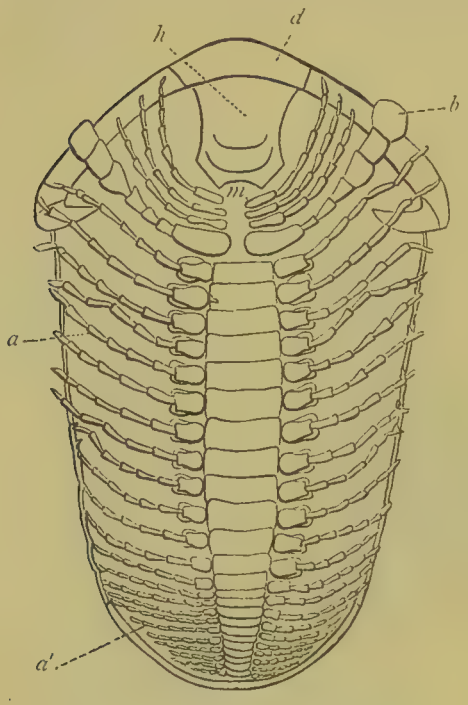


Fig. 379.—Restoration of the under surface of *Calymene Blumenbachii*, showing the appendages. *d*, Doublure of the cephalic shield; *h*, Hypostome; *b*, The last pair of cephalic appendages (maxillipedes); *m*, Mouth, bounded by the jaws; *a*, Thoracic limbs; *a'*, Abdominal limbs. (After Walcott.)

As to their *mode of life*, the Trilobites, as before remarked, seem to have delighted in muddy bottoms, though often found in limestones, and they must have frequented particular localities in vast numbers. In connection with this subject, we may briefly notice certain tracks or markings in the rocks, which may perhaps have been pro-

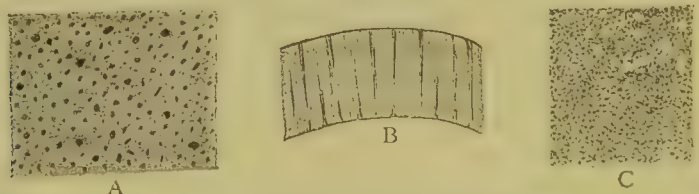


Fig. 380.—A, Tangential section of the crust of *Calymene senaria*, showing the openings of large and small tubes; B, Vertical section of the same; C, Tangential section of the crust of *Asaphus Canadensis*, showing a minutely porous structure. All the figures are greatly magnified. (Original.)

duced by these extraordinary extinct Crustaceans, or by their allies the King-crabs and Eurypterids. The most interesting of the tracks in question are those which have been described by Professor Owen from the Potsdam Sandstone (Upper Cambrian) of Canada, under the name of

Protichnites. The tracks upon which this genus is founded (fig. 381, A and B) consist essentially of a median groove, with a number of depressions or footprints on each side in corresponding pairs, these being often arranged in answering groups, of seven or eight pairs each. Sometimes the pits or footprints are replaced by shallow grooves, on each side of the main median groove (fig. 381, B). The tracks of *Protichnites* indicate the existence in the Upper Cambrian of some animal of very considerable size, since they are sometimes half a foot or more in width. That the animal producing these tracks was a Crustacean can hardly be doubted; the median groove being made by the tail-spine, and the lateral markings by the feet; and as we know that large Trilobites actually lived during this period, it seems most reasonable to suppose that we have in these the real makers of the tracks. Sir William Dawson, however, has shown that tracks of a closely similar nature are formed by the living

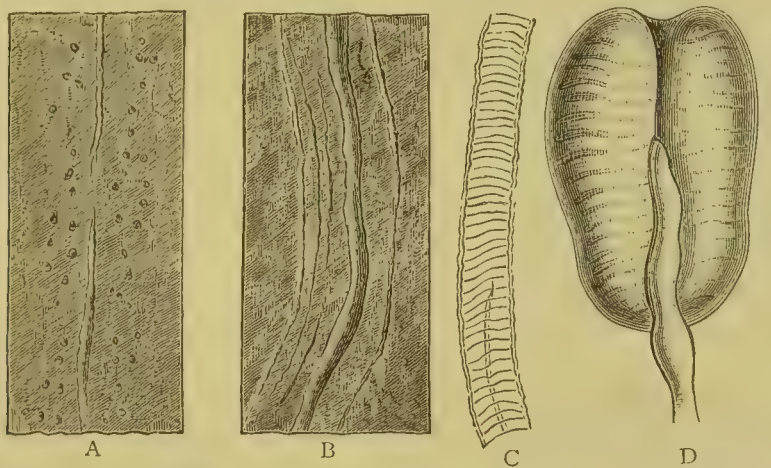


Fig. 381.—Supposed Crustacean tracks and burrows. A, Portion of the track of *Protichnites alternans*, from the Potsdam Sandstone, reduced to one-tenth of the natural size; B, Portion of the track of *Protichnites lineatus*, from the same formation, similarly reduced; C, Portion of *Climactichnites Wilsoni*, from the Potsdam group, reduced to one-thirtieth of the natural size; D, *Rusichnites* (*Rusophycus*) *bilobatus*, from the Clinton formation (Silurian), reduced one-half. (After Owen and Hall.)

King-crabs (*Limulus*), and he would therefore ascribe *Protichnites* rather to the Eurypterids. The same eminent observer has also shown that smaller forms of *Protichnites* occur in the Carboniferous; and he ascribes these to the Limuloid genus *Belinurus*. The curious track known as *Climactichnites* (fig. 381, C) is likewise found in the Potsdam formation, and consists of a band about six inches wide, crossed by straight ridges, and bounded by beaded margins. These were probably formed by the same animal as that which produced *Protichnites*, and Dawson has shown that the living *Limulus*, when it uses its swimming-feet, gives rise to a ladder-like track of the same kind. Prof. Chapman believes that both *Protichnites* and *Climactichnites* are really of vegetable origin. The only other fossil which need be mentioned in this connection is the curious *Rusichnites*, which is of common occurrence in the Ordovician and Silurian rocks of North America, and is also found in the Carboniferous. Originally described as a plant under the name of *Rusophycus*, its name was changed by Dawson to *Rusichnites*, in accordance with his belief that it really represents the *casts* of the bur-

rows of Trilobites, and that it can be shown to be sometimes connected with footprints consisting of a double series of transverse markings. In form, *Rusichnites* (fig. 381, D) presents itself as an oval, cylindroidal body, deeply furrowed, or bilobed, by means of a longitudinal sulcus, the lateral halves being transversely ridged or grooved. The body thus constituted may be independent, or may stand in apparent connection with a cylindrical and slender appendage.

With regard to their *systematic position*, the Trilobites have been usually regarded as Entomostracous Crustaceans, with relationships to the Phyllopods and to the *Merostomata;* but they have been sometimes considered as related to the Isopods. With regard to these last, there is no doubt a considerable general likeness between such an Isopod as *Serolis* and various forms of the Trilobites; and a tangible point of resemblance is found in the fact that in many Isopods the caudal segments coalesce to form a shield like the pygidium of the Trilobites. On the other hand, the segmentation of the body in the Trilobites is indefinite, the number of limbs is large, and thoracic branchiæ are developed; whereas in the Isopods the segmentation of the body is definite, there are only seven pairs of legs, and the branchiæ are abdominal. With the Phyllopods, the Trilobites are in agreement as regards the indefinite segmentation of the body; and the recent genus *Apus* possesses a lip-plate which in form is very similar to that of the Trilobites. The Trilobites, however, have a calcareous crust; their limbs are jointed, and not phyllopodous; and the segments of the abdomen are anchylosed. There are, finally, remarkable points of relationship between the Trilobites and the *Merostomata*, and particularly between the former and the Limuloid types of the latter. Thus, the Trilobites show affinities with the *Merostomata* in the possession of a very similar head-shield to that of the latter, the presence (particularly in some extinct Limuloids) of distinct indications of a "facial suture," the existence of compound sessile eyes, and the microscopic structure of the crust. Moreover, the larva of the recent *Limulus* (fig. 382) is destitute of the tail-spine of the adult, and in many respects shows a striking resemblance to certain of the Trilobites, and particularly to the genus *Trinucleus*. There are, however, various striking points of difference between the Trilobites and the Limuloids. Thus the former always possess free thoracic segments, and the appendages carried on these differ en-

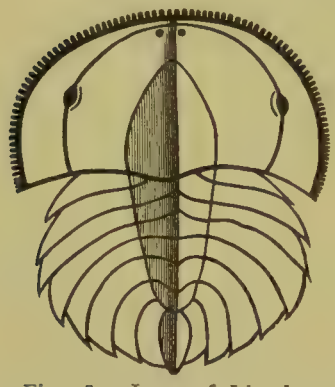


Fig. 382.—Larva of *Limulus* on hatching, greatly enlarged. (After Dohrn.)

tirely from those borne on the same region in any of the *Merostomata*. Again, the Trilobites have no "ocelli," and have a well-developed hypostome. On the other hand, the thoracic somites in the Limuloids may be completely anchylosed (as they are in *Limulus* itself); ocelli are present as well as compound eyes; and the hypostome is rudimentary or absent. Upon the whole, in spite of the above-mentioned differences, it would seem that the Trilobites are more nearly related to the *Merostomata* than to any other group of the *Crustacea*, and if, as maintained by Claus and other high authorities, the latter are properly referable to the *Arachnida*, it will be apparently necessary to transfer the *Trilobita* also to this class of the *Arthropoda*. Apart, however, from the difficult question as to whether the Limuloids and Eurypterids are referable to the *Arachnida* or to the *Crustacea*, it may be questioned if there is sufficient justification, in the present state of our knowledge, for placing these two groups along with the Trilobites in the common division to which Claus has given the name of *Gigantostraca*. The differences between the *Trilobita* on the one hand, and the *Xiphosura* and *Eurypterida* on the other hand, are, at any rate, so numerous that it would be a matter of difficulty to frame a definition of the *Gigantostraca* which would embrace these three orders, and would at the same time exclude all the other groups of the *Crustacea*.

The general facts as to the *distribution* of the *Trilobita* in past time are soon told. The Trilobites are exclusively Palæozoic, their range extending from the Upper Cambrian to the Permian. If the problematical *Palæopyge Ramsayi* of the Longmynd beds be a Trilobite, then the order has its commencement in the Lower Cambrian. In the Upper Cambrian rocks the order attained a wonderful development, the number of generic and specific types already known from this formation being very large, while individuals are sometimes extremely abundant. Some of these so-called "Primordial" Trilobites attain a very great size, being only surpassed amongst later forms by some species of *Asaphus*. They mostly belong to the families of the *Agnostidæ*, *Conocephalidæ*, and *Paradoxidæ*, and to the genera *Paradoxides*, *Conocoryphe*, *Sao*, *Ellipsocephalus*, *Hydrocephalus*, *Arionellus*, *Dikellocephalus*, &c. Along with these, however, are genera such as *Agnostus*, which pass up into the Ordovician. Some of the "Primordial" Trilobites are not so highly organised as their successors, as shown by the occasional absence of eyes, or want of the facial suture, by the imperfect segmentation of the glabella, or by the multiplication or diminution of the number of the body-rings; but others do not exhibit any inferiority to those of later periods.

In the Ordovician and Silurian rocks the Trilobites attain their

maximum of development, the leading families being the *Asaphidæ*, *Phacopidæ*, *Trinucleidæ*, *Cheiruridæ*, and *Calymenidæ*, and the chief genera being *Asaphus*, *Ogygia*, *Phacops*, *Trinucleus*, *Ampyx*, *Cheirurus*, *Encrinurus*, *Calymene*, and *Homalonotus*. In the Devonian rocks, again, Trilobites are tolerably abundant, though less so than in the preceding series. The commonest Devonian genera are *Phacops*, *Homalonotus*, *Proetus*, and *Bronteus*. Lastly, the order seems to die out before the close of the Palæozoic epoch, being represented in the Carboniferous period solely by the four genera *Phillipsia*, *Brachymetopus*, *Griffithides*, and *Proetus;* while in the Permian rocks only a single species of *Phillipsia* has hitherto been detected.

In the following, a brief summary of the families of the *Trilobita*, indicating the principal genera of each, and their distribution in time, will be given. No strictly zoological arrangement of these families is as yet possible, except in a general sense, but the classification proposed by M. Barrande, one of the most illustrious palæontologists of this century, has been in the main adhered to.



Fig. 383.—*Harpes ungula*, from the Silurian of Bohemia. (After Barrande.)

Family 1. Harpedidæ.—Cephalic shield large, and horse-shoe-shaped, its posterior angles greatly prolonged, and its margin or "limb" perforated by pores (fig. 383). The glabella is conical and prominent, with slightly marked furrows, and the eyes are small, and consist of a few lenses. There are from twenty-five to twenty-nine thoracic segments, and the pygidium is extremely small, and consists of three or four amalgamated segments. The species of *Harpes*, the sole genus comprised in this family, are principally Ordovician and Silurian, but a few Devonian forms are known.

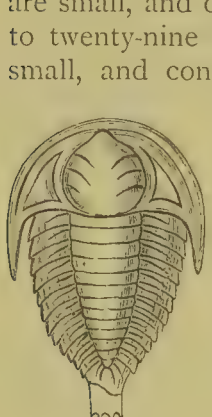


Fig. 384.—*Remopleurides radians*. Ordovician. (After Barrande.)

Family 2. Remopleuridæ.—In this family the head is greatly developed, semicircular in shape, the genal angles produced into spines. The glabella is smooth, or possesses three pairs of lateral grooves, and the facial sutures unite in front of it. The eyes are very long and are reticulated. There are eleven to thirteen body-rings, with grooved pleuræ, and the pygidium is very small, and is often reduced to two segments. This family contains only the single genus *Remopleurides* (fig. 384), which is confined to the Ordovician and Silurian deposits.

Family 3. Paradoxidæ or Olenidæ.—Head-shield well developed, crescentic, the genal angles produced. The glabella, typically, widest anteriorly, with well-marked grooves. The facial

sutures nearly parallel, cutting the head-shield separately; the eyes large. The body is very long (fig. 385, *a*); the thorax has from twelve to twenty segments, with grooved pleuræ; the pygidium being usually small and of few segments. The family is essentially characteristic of the Cambrian deposits, ranging through all the divisions of this formation.

The principal genus of this group is *Paradoxides* itself (fig. 385, *a*, and fig. 386), with its long and trilobed body, sometimes reaching a length of two feet or more. The thorax in this genus is greatly

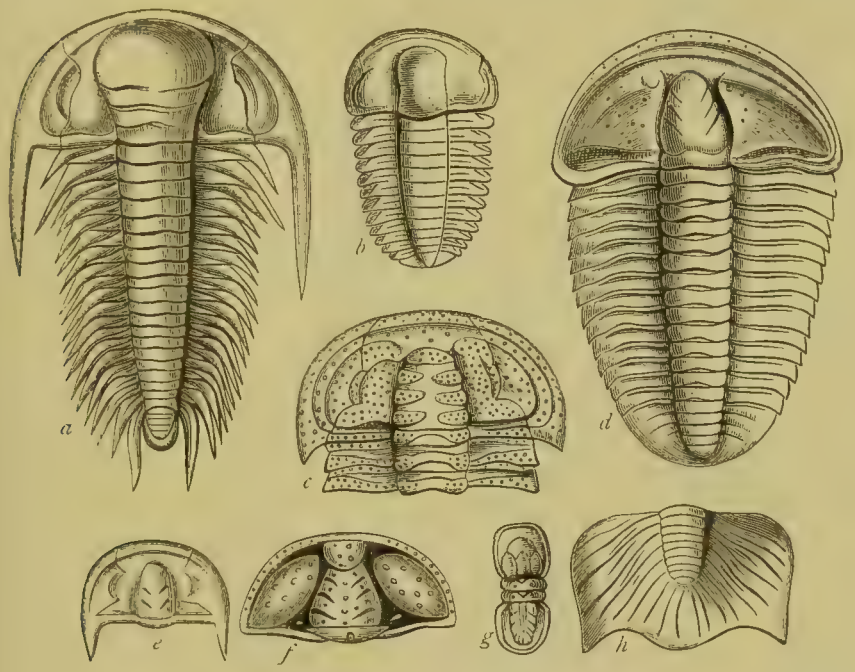


Fig. 385.—*Paradoxidæ* and *Conocephalidæ*. *a*, *Paradoxides Bohemicus*, reduced in size; *b*, *Ellipsocephalus Hoffi*; *c*, *Sao hirsuta*; *d*, *Conocoryphe Sultzeri*—(all the above, together with fig. *g*, are from the Upper Cambrian or "Primordial Zone" of Bohemia); *e*, Head-shield of *Dikellocephalus Celticus*, from the Lingula Flags of Wales; *f*, Head-shield of *Conocoryphe Matthewi*, from the Upper Cambrian (Acadian Group) of New Brunswick; *g*, *Agnostus rex*, Bohemia; *h*, Tail-shield of *Dikellocephalus Minnesotensis*, from the Upper Cambrian (Potsdam Sandstone) of Minnesota. (After Barrande, Dawson, Salter, and Dale Owen.)

elongated, and consists of sixteen or twenty rings, while the axis of the pygidium often contains two segments only. The eyes are long, reniform, and smooth. The genus is characteristic of, and confined to, the Cambrian period. *Plutonia* and *Anopolenus*, with a similar geological range, are closely related to *Paradoxides;* but the former of these two genera has a narrow glabella and a tuberculated surface, while the latter has the last two pleuræ of the thorax dilated and bent backwards, and the pygidium has wide lateral lobes. The genus *Olenellus* resembles *Paradoxides* in most respects, but

there are only thirteen or fourteen segments in the thorax, and the lateral lobes of the pygidium are undeveloped, the elongated and pointed axis alone remaining. The genus *Olenellus* appears to be characteristic of the Lower Cambrian deposits, while *Paradoxides* distinguishes the Middle Cambrian fauna, and *Olenus* (or *Dikellocephalus*) the Upper Cambrian.

In *Hydrocephalus*, again, the glabella is immensely inflated, with a median longitudinal groove; and the facial sutures cut the outer

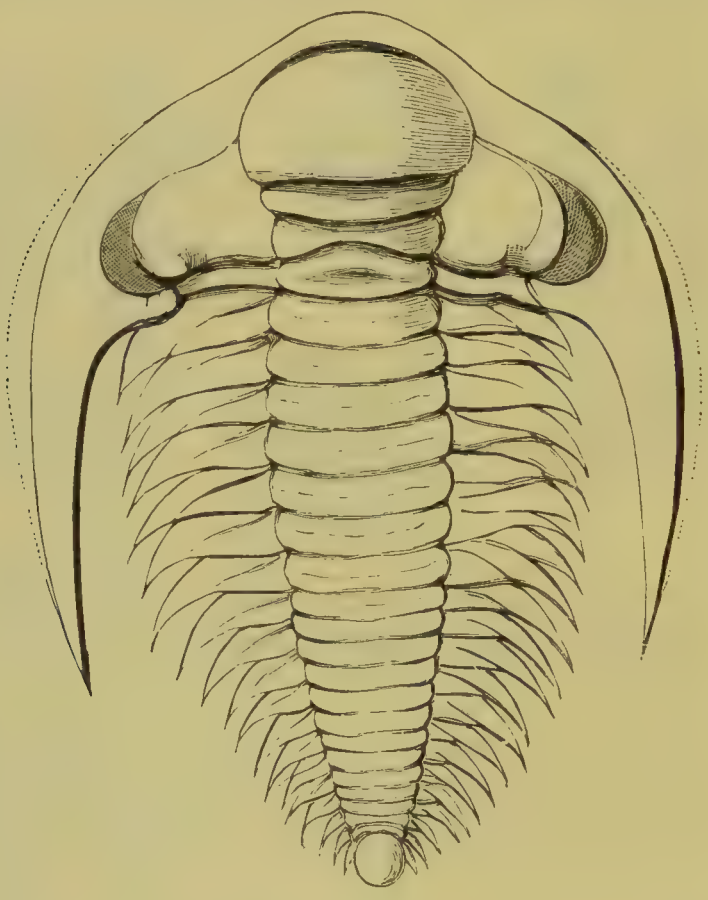


Fig. 386.—*Paradoxides Micmac.* St John's Group (Cambrian), Newfoundland. (After Dawson.)

margins of the head-shield, so that the free cheeks become much reduced in size, and the genal spines are attached to the fixed cheeks. Eyes are wanting, and there are only twelve body-rings. A more important and widely distributed genus of this family is *Olenus* (fig. 387), in which the general characters are very similar to those of *Paradoxides*, but the glabella is contracted in front so as to become conical, and its furrows are often extended completely

across it: there are only fourteen body-rings; and the pygidium is well developed. *Parabolina* includes *Oleni* with only twelve body-rings, and with a spined margin to the pygidium; while *Peltura* embraces forms in which the hinder angles of the head-shield are rounded, and the glabella is prolonged forwards to the front margin. *Olenus* and its sub-genera are confined to the Cambrian period, and specially distinguish the Upper Cambrian desposits. Characteristic of the same geological horizon is the genus *Dikellocephalus* (figs. 375, and 385, *h*) in which the most striking feature is the broad, fanlike, often spined tail, with its short many-ringed axis. The facial sutures cut the margin of the head-shield separately in front, and the grooves of the glabella are like those of many *Oleni* in joining from side to side.

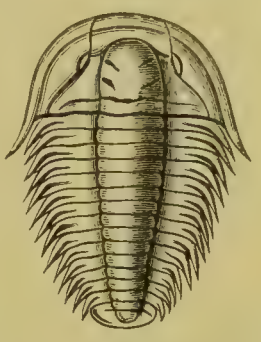


Fig. 387.—*Olenus micrurus*, from the Upper Cambrian. (After Salter.)

Family 4. CONOCEPHALIDÆ.—This family is a convenient one to retain, though it does not seem at present possible to separate it from the preceding by any rigid definition. Its members resemble the *Paradoxidæ* in general characters, but the glabella is narrow in front, or, at any rate, not dilated in this region, and the tail is usually fairly well developed, while the thoracic rings are not so numerous as in the typical forms of the latter. Moreover, most of the members of the *Conocephalidæ* have the power of rolling up into a ball. The type-genus is *Conocoryphe* or *Conocephalites* (fig. 385, *d* and *f*), which has resemblances to both *Olenus* and *Calymene*, its glabella approaching that of the latter in its comparatively great posterior width and its contraction in front. Eyes are usually, but not always present; the facial sutures are discontinuous; the fixed cheeks are large and the free cheeks small; and there are fourteen or fifteen body-rings, while the tail has from two to eight rings. The genus is represented by very numerous species in the Upper Cambrian, and also occurs in the Ordovician rocks. *Ellipsocephalus* (fig. 385, *b*) is related to the preceding, but the glabella is subquadrate, smooth, and convex, and there are twelve to fourteen body-rings. *Angelina* (fig. 388) is another Upper Cambrian genus, with affinities to *Olenus*. Its glabella, however, is destitute of grooves, and the tail is composed of four or five rings, while the body-segments are fifteen in number. The genus *Sao* (fig. 385, *c*), of the same formation, is a link between the present family and the *Paradoxidæ*. It is distinguished by its prominent furrowed glabella, the possession of seventeen body-rings, and the minute tail of two segments only. *Arionellus*, also Cambrian, has sixteen body-rings, and three caudal segments; and the allied genus *Menocephalus*, of

the same age, is chiefly separated from the former by its much more convex glabella. Lastly, *Bathyurus* (Upper Cambrian and Ordovician) and *Bathyurellus* (Ordovician) form in some respects intermediate types between the *Conocephalidæ* and the *Asaphidæ;* and the Olenoid genus *Triarthrus* survives to near the middle of the Ordovician period.

Family 5. BOHEMILLIDÆ.—This family contains only the Ordovician genus *Bohemilla*, characterised by its greatly developed head; the glabella being of large proportionate size, with four pairs of lateral grooves, the hinder ones of which pass completely from side to side, so as to divide this region of the head into regular rings or

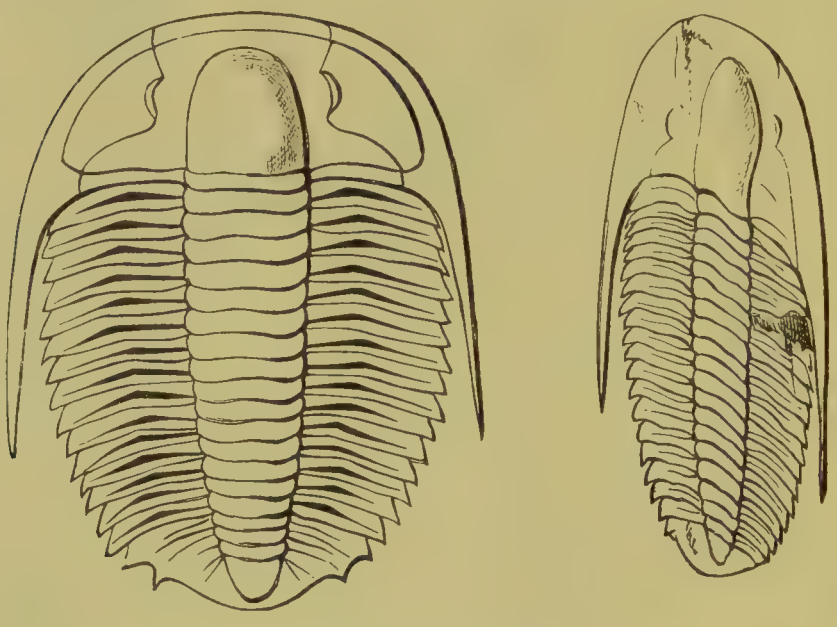


Fig. 338.—*Angelina Sedgwickii*, in its natural condition, and distorted by cleavage. Upper Cambrian. (After Salter.)

segments, closely resembling those of the thoracic axis. The eyes are large and reticulated; the course of the facial sutures is unknown; the genal angles are prolonged into long spines, directed transversely rather than backwards; and the thorax and pygidium are not clearly marked off from one another, the former consisting apparently of five segments and the latter of two.

Family 6. CALYMENIDÆ.—In this family the crust is often tuberculated or granulated; the head is well developed; the glabella is widest behind; and the facial sutures are discontinuous, and terminate at the posterior angles of the cephalic shield. There are thirteen segments in the thorax, with grooved pleuræ; the tail is of moderate size; and the condition of the eyes is variable. In

Calymene itself (fig. 372) the head is usually crescentic, with rounded genal angles; and the glabella is conical, strongly convex, with deep axal furrows, and divided by three deep lateral grooves on each side, all the "lobes" thus formed being globose, and the hindmost being the largest. The eyes are minute and reticulated, but are rarely recognisable. The tail is convex, with a well-marked axis, and the hypostome is quadrate and forked posteriorly. The animal possessed in perfection the power of rolling up into a ball, specimens commonly occurring in this condition. The species of *Calymene* are principally Ordovician and Silurian, and the three most familiar species are the nearly allied *C. Blumenbachii*, *C. senaria*, and *C. brevicapitata*. The genus is also known to have survived, in North America, into the commencement of the Devonian period.

The genus *Homalonotus* is the only other member of the *Calymenidæ*, and is distinguished from *Calymene* by the greatly elongated and faintly trilobed body (fig. 389). The glabella, further, is smooth or exhibits but faint traces of lobation. The species of *Homalonotus* are Silurian and Devonian, and the genus has a wide distribution in space. A very familiar species is the *Homalonotus delphinocephalus* of the Silurian rocks.

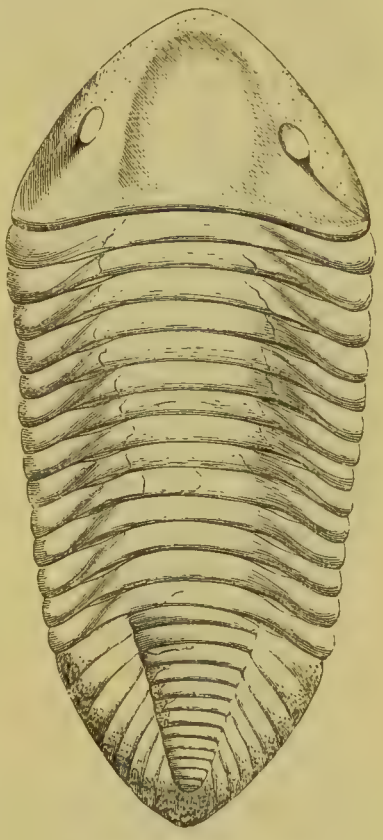


Fig. 389.— *Homalonotus delphinocephalus*. Silurian.

Family 7. ASAPHIDÆ. — Large Trilobites, generally oval, and never furnished with spines or tubercles on their surface. The eyes smooth, and the facial sutures terminating on the posterior margin. The cephalic and caudal shields generally of large size, the glabella of the former often obscure, and the latter sometimes exhibiting no indication of its component segments. The body-rings usually eight in number, with grooved pleuræ. The family is characteristically Ordovician, and the two principal genera are *Asaphus* and *Ogygia*. In the genus *Asaphus* (figs. 390, 392, 393) the general trilobation is somewhat indistinct, and the caudal shield is generally equal to the head in size. The genal angles of the head-

shield may be rounded or spinose, and the glabella is not marked off by conspicuous axal furrows. The facial sutures are discontinuous, the eyes crescentic, the hypostome deeply forked, and the pygidium may or may not show a conspicuous axis, its hinder extremity being usually rounded, and its margin always entire. This important genus is characteristic of the Ordovician rocks, and the species have a world-wide distribution, some of the forms attaining the extraordinary size of two feet in length. The genus *Asaphus* has been divided into a number of sub-genera, of which *Isotelus* and *Megalaspis* are the most important. In the former of these (fig. 392) the axis is very wide, the glabella is imperfectly marked off,

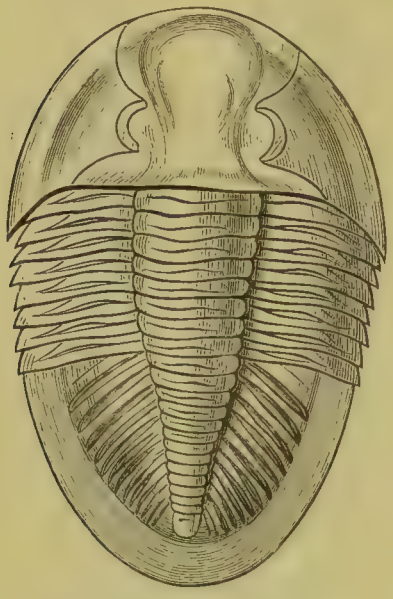


Fig. 390.—*Asaphus tyrannus.* Ordovician. (After Salter.)

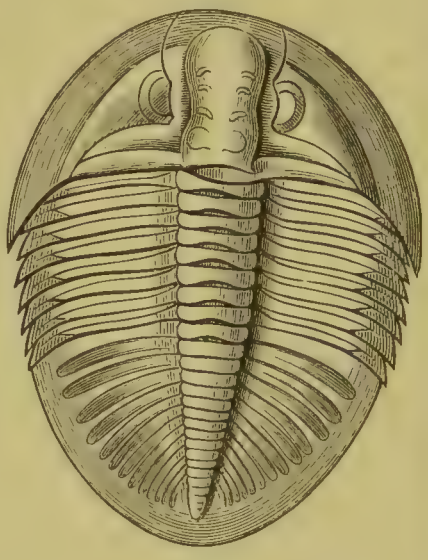


Fig. 391.—*Ogygia Buchii.* Ordovician. (After Salter.)

and the pleuræ have rounded ends. In *Megalaspis* (fig. 393), on the other hand, the axis is narrow, the glabella is very short, and the head-shield is usually greatly extended in front.

The genus *Ogygia* is closely allied to *Asaphus* in general form and proportions; but the axis of the pygidium is more conspicuously marked than in most *Asaphi* (fig. 391), the hypostome is *rounded* and not cleft, the glabella is distinctly furrowed, and the pleuræ of the thoracic segments have only rudimentary "fulcra." The species of *Ogygia* are confined to the Ordovician rocks. This is also the case with the genus *Niobe*, which is in some respects intermediate between *Asaphus* and *Ogygia*, having the round hypostome and lobed glabella of the latter, while it approaches the former in its wide glabella and its obtuse and faceted pleuræ. The Ordovician

genus *Stygina* is related to *Ogygia*, but the head-shield and pygidium are very similar. Lastly, the Upper Cambrian genus *Psilocephalus* forms a link between *Asaphus* and *Illænus;* while the genus *Nileus* might be almost indifferently placed with either the *Asaphidæ* or the *Illænidæ*.

Family 8. Illænidæ.—In this family the head and tail are greatly developed, and, as in the *Asaphidæ*, are approximately equal in size (fig. 394). The glabella is broad and rounded, destitute of lobes, and with the axal furrows hardly at all marked. There are eight to

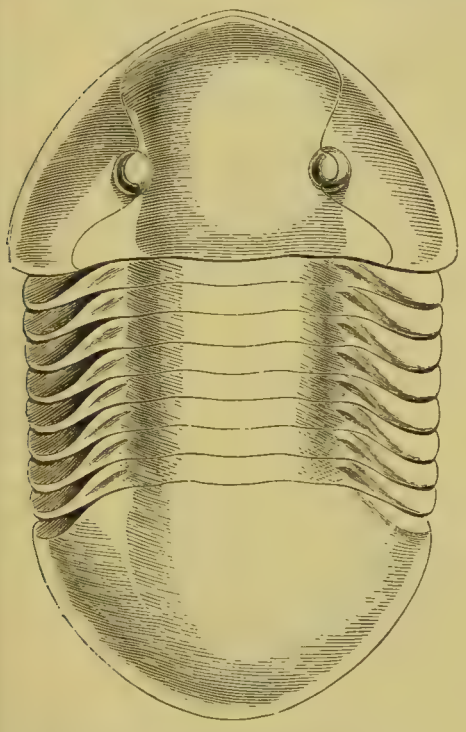


Fig. 392.—*Asaphus* (*Isotelus*) *platycephalus*. Ordovician.

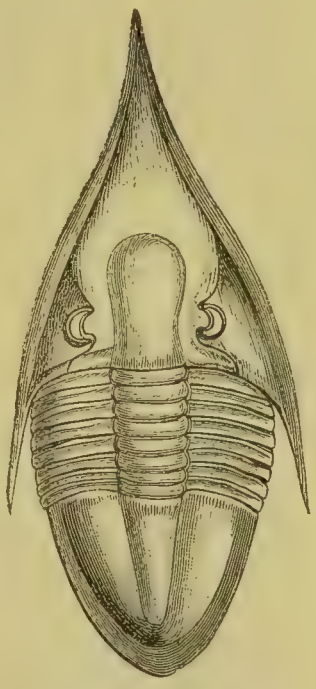


Fig. 393.—*Asaphus* (*Megalaspis*) *extenuatus*, of the natural size. Ordovician, Sweden. (After Angelin.)

ten body-rings; and the axis of the tail is truncated or wanting, and in no case exhibits definite segmentation. The free cheeks are extremely small; the facial sutures are separate; and the eyes are crescentic.

If *Nileus* be regarded as belonging to the *Asaphidæ*, the only well-defined genus in this family is *Illænus* itself (fig. 394). In this genus the head is large, convex, and tumid, as is also the tail, the glabella and pygidial axis being hardly marked out, and being wholly unsegmented. In the typical forms of this group (*Illænus* proper), the axis of the thorax is not disproportionately wide, and

the axal furrows are distinct; but in others (*Bumastus*), the thoracic axis is extremely wide, and is hardly separated from the pleuræ by

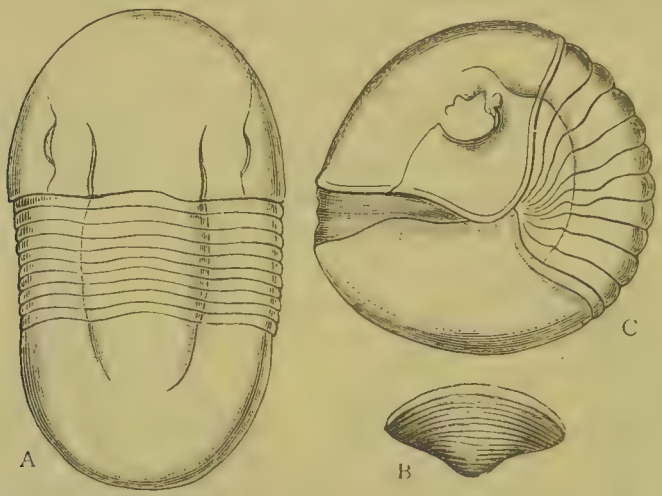


Fig. 394.—A, A complete example of *Illænus Davisii*, in its unrolled state—Ordovician; B, Hypostome of the same; C, *Illænus* (*Bumastus*) *Barriensis*, rolled up—Silurian. (After Salter.)

recognisable axal furrows (fig. 374). In the former of these sections there are ten body-rings; whereas in *Octillænus* and *Panderia* there

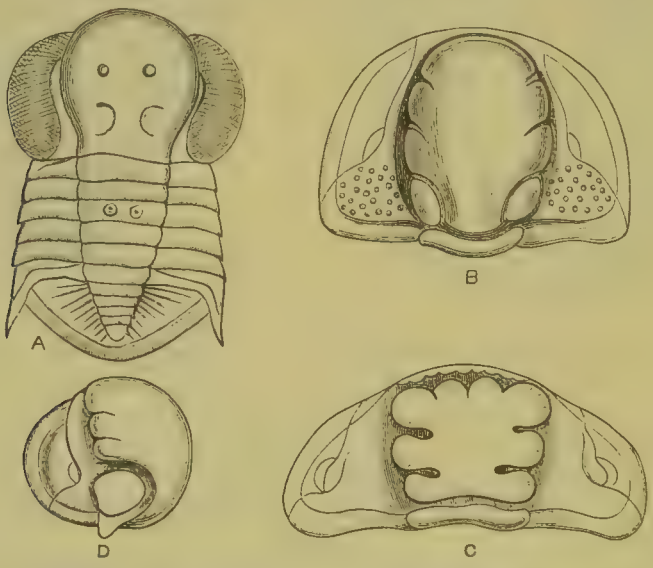


Fig. 395.—A, *Æglina prisca*—Ordovician; B, Head-shield of *Cheirurus juvenis*—Ordovician; C, Head-shield of *Amphion Fischeri*—Ordovician; D, Side view of the head-shield of *Sphærexochus mirus*—Ordovician and Silurian. (After Barrande and Salter.)

are only eight body-rings, and in *Dysplanus* there are nine. The species of *Illænus* are exclusively confined to the Ordovician and Silurian periods.

Family 9. Æglinidæ.—This family contains only the single genus *Æglina* (fig. 395, A), of the Ordovician rocks, and is chiefly distinguished from the preceding by the much larger size of the eyes, and the smaller number of body-rings. The head and tail are both of large size, the latter with a truncated axis; the glabella is not conspicuously marked out; the facial sutures are discontinuous; and the eyes are extremely large and reticulate; while the segments of the thorax are reduced to five or six in number.

Family 10. Cheiruridæ.—In this large and important family the head-shield is well developed, with discontinuous facial sutures, which terminate on its outer margin. The glabella is usually highly convex or tumid, with well-marked axal furrows and lateral grooves. There are ten to twelve, rarely fifteen or eighteen, generally eleven, body-rings, and the pygidium is small, of from three to five segments, the pleuræ terminating in free ends. The family ranges from the Upper Cambrian to the Devonian, but is principally characteristic of the Ordovician and Silurian rocks. In *Cheirurus* itself (figs. 395, B, and 396) the head is semicircular, with rounded or pointed genal angles, and with a strongly-arched glabella, which is deeply grooved by the lateral furrows. There are generally eleven body-rings, with ridged or slightly grooved pleuræ; and the tail has a well-marked axis of four rings, its pleuræ being prolonged into points or spines. *Amphion* (fig. 395, C) is nearly related to *Cheirurus*, but has from fifteen to eighteen body-rings, and exhibits minor differences as well. *Placoparia*, again, agrees with *Cheirurus* in having eleven body-rings, and also in the form and lobation of the glabella, but it is destitute of both eyes and facial sutures, as is also the genus *Areia*. *Sphærexochus*, lastly (fig. 395, D), while agreeing with *Cheirurus* generally, is distinguished by the extreme inflation of the glabella, and the presence of no more than three segments in the pygidium; while the basal lobes of the glabella are completely isolated, and there are only ten body-rings. We may also place here the very singular and aberrant genera *Staurocephalus* and *Deiphon*. In the former of these the general characters correspond with those of *Cheirurus*, but the anterior or "frontal" portion of the glabella is enormously swollen, and forms a great globular projection in advance of the line of the cheeks. The species of *Staurocephalus* are Ordovician and Silurian. In the

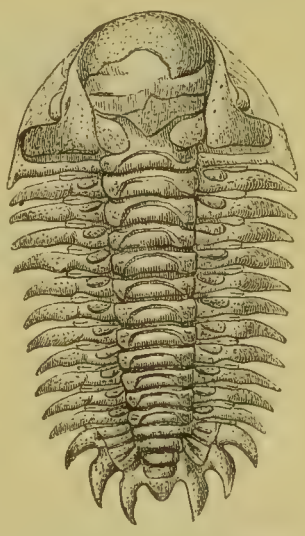


Fig. 396.– *Cheirurus insignis*, from the Silurian rocks of Bohemia. (After Barrande.)

still more curious *Deiphon*, of the Silurian rocks, the fixed cheeks are rudimentary, and are reduced to two curved spines, which spring from the sides of the swollen glabella, and carry the faceted eyes, while the free cheeks are obsolete. The axis of the tail is formed of four or five rings, and the pleuræ are prolonged into two spines on each side, one of these being formed by the first segment only, while the other, and much larger, one is made up of the amalgamated extremities of the remaining segments.

Family 11. Encrinuridæ. — This family is confined to the Ordovician and Silurian periods, and is related to the preceding through the intervention of *Amphion*. The head is fairly devel-

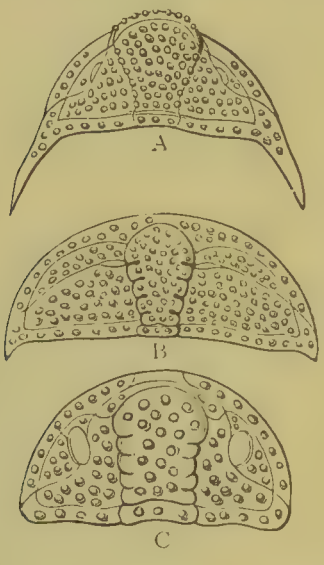


Fig. 397.—A, Head-shield of *Encrinurus punctatus* — Silurian; B, Head-shield of *Cromus intercostatus*—Silurian; C, Head-shield of *Cybele bellatula* — Ordovician. (After Barrande.)

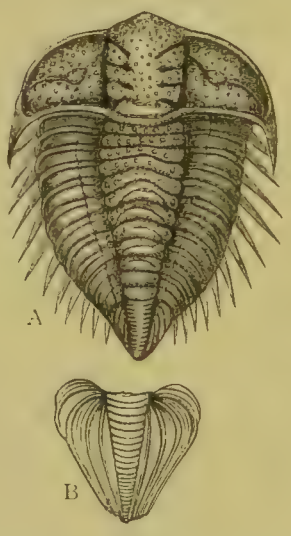


Fig. 398.—A, *Cybele Loveni*, of the natural size; B, Cast of the pygidium of *Cybele verrucosa*, enlarged twice. From the Ordovician rocks of Girvan. (After R. Etheridge, jun., and the Author.)

oped, the genal angles rounded or pointed, and the facial sutures discontinuous, and cutting the outer angles of the cephalic buckler. Eyes are present, though not of large size, and the glabella may or may not exhibit distinct lateral grooves. The surface is tuberculated, and some or all of the body-rings may bear spines. The thorax generally consists of eleven segments; and the tail, though moderate in size, has a well-marked axis, which is composed of very numerous rings.

In *Encrinurus* (fig. 397, A) the glabella is pyriform, strongly tuberculated, with the lateral furrows almost obsolete. The body-rings are eleven in number, and the axis of the pygidium is composed of extremely numerous rings. In this genus, as in its near

ally *Cybele*, the pygidium is long and triangular, and has its pleuræ bent backwards so as ultimately to become parallel with the axis (fig. 398, B). The range of the genus *Encrinurus* is principally Silurian, but the genus likewise occurs in the higher portion of the Ordovician series. The genus *Cybele* (= *Zethus*, Volborth) is distinguished from *Encrinurus* chiefly by its clavate glabella (fig. 397, C) and its possession of twelve body-rings, which are usually produced into spines (fig. 398, A). The facial sutures cut the margin of the head-shield close to the genal spines, and the tail resembles that of *Encrinurus* in form. The genus is characteristic of the Ordovician rocks. Lastly, in the Silurian genus *Cromus* (fig. 397, B) the gla-

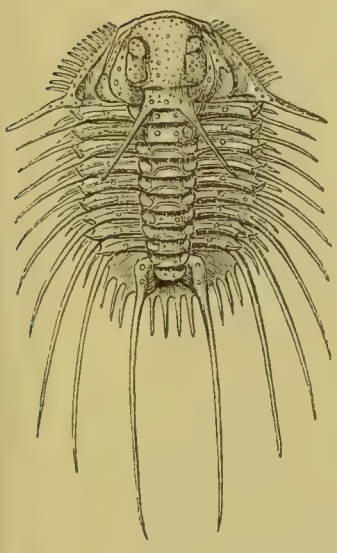


Fig. 399.—*Acidaspis Dufrénoyi*, from the Silurian rocks of Bohemia. (After Barrand—Copied from Zittel.)

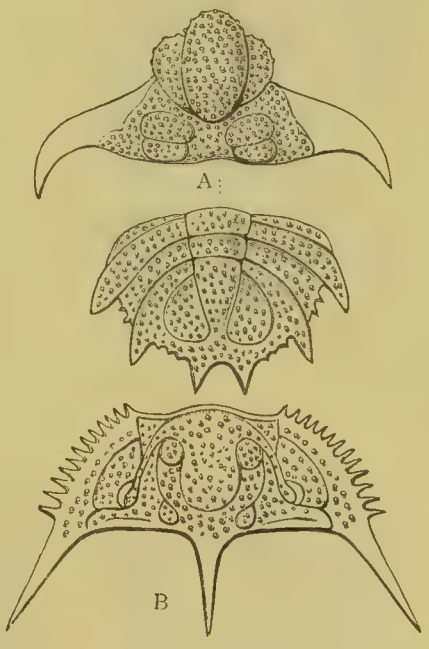


Fig. 400.—A, Head-shield and tail of *Lichas palmata*; B, Head-shield of *Acidaspis Hoernesi*. Silurian rocks of Bohemia. (After Barrande.)

bella has four well-marked lateral grooves; the eyes are small and ovoid; and the pygidium looks like a continuation of the thorax, its axis being composed of from twelve to twenty-eight rings, and its pleuræ terminating in free points.

Family 12. Dindymenidæ.—In *Dindymene*, of the Ordovician formation, the only genus which can be certainly referred to this family, the head-shield is semicircular, with a tumid glabella, destitute of lateral grooves. There are no eyes, nor facial sutures; and the cheeks are tumid, as in *Trinucleus*. There are ten body-rings, and the tail is large and distinctly segmented.

Family 13. Acidaspidæ.—Like the preceding, this family contains only a single genus—viz., *Acidaspis* itself. In this characteristically Silurian type (fig. 400, B), the usual form of the head-shield in the Trilobites is somewhat masked, the trilobation being rendered indistinct by the presence of an additional and secondary pair of axal furrows, which mark off a central inflated portion of the glabella. The thorax has nine or ten rings, with ridged pleuræ, which are terminated by spines; while the tail is very small, and has its margin fringed with spines (fig. 399). The facial sutures are continuous, or are sometimes wanting; and the eyes are of small size and smooth. The species of *Acidaspis* are found in the Silurian and Devonian rocks, and are usually readily recognised by their highly ornamented and spinose crust.

Family 14. Lichadæ.—The principal or only genus in this family is *Lichas*[1] itself (fig. 400, A), in which the body is broad and oval, and the crust is superficially more or less granulated or tuberculated. The head-shield is transversely elongated and very convex, and the glabella as a rule is not very clearly separated from the cheeks. The frontal grooves of the glabella are extended backwards, so as to enclose a central lobe. The facial sutures cut the anterior margin separately, and the eyes are small and smooth. There are nine or ten thoracic rings, with grooved pleuræ; and the pygidium is larger than the head, and often presents prominent spinose ends to its component rings. The species of *Lichas* are Ordovician, Silurian, and Devonian.

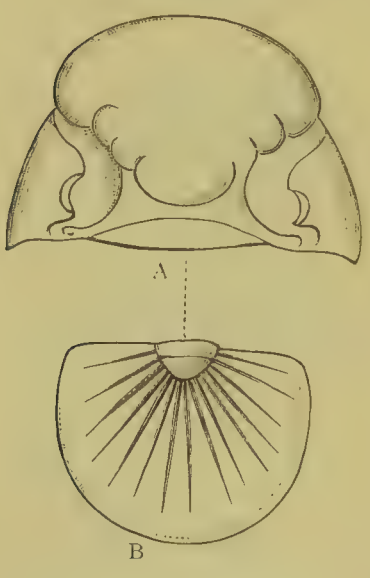


Fig. 401.—A, Head-shield of *Bronteus campanifer*, from the Silurian rocks of Bohemia; B, Tail of the same. (After Barrande.)

Family 15. Bronteidæ. — This family includes only the genus *Bronteus*, the species of which are found in the Ordovician, Silurian, and Devonian rocks. In this well-marked type (fig. 401) the body is broad, and could be rolled up, both the head-shield and the pygidium being of great size. The tail is particularly large, and is always more or less fan-shaped, the axis being short and rudimentary, while the "limb" is greatly developed. The head-shield is trilobed, the glabella being dilated in front, the

[1] The genus *Lichas* has been very fully treated of by Magister Friedrich Schmidt ('Revision der Ostbaltischen Silurischen Trilobiten,' Abth. II., 1885), by whom it has been split up into a number of sub-generic groups.

facial sutures being separate, and the eyes sickle-shaped. There are ten thoracic segments, and the pleuræ are ridged.

Family 16. Phacopidæ.—In this, one of the best-marked and most typical of the families of the Trilobites, the head is well developed, the glabella conspicuously broadest in front, with three or four lateral grooves, and the facial sutures united in front of the glabella, and cutting the outer margins of the cephalic buckler behind. The eyes are usually large, and are faceted (fig. 403); there are eleven body-rings, with grooved pleuræ; and the condition of the pygidium is variable. The hypostome is convex, and more or less

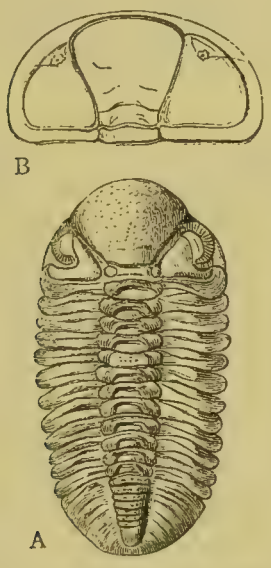


Fig. 402.—A, *Phacops Sternbergi*, from the Silurian rocks of Bohemia; B, Head-shield of *Phacops* (*Trimerocephalus*) *Volborthi*, Silurian, Bohemia. (After Barrande. Copied from Zittel.)

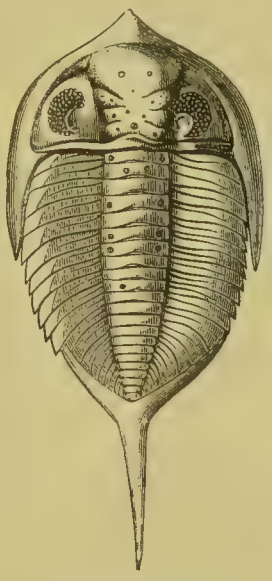


Fig. 403.—*Phacops* (*Dalmanites*) *longicaudata*. Silurian (Wenlock) of Britain and North America.

triangular in shape. The genus *Phacops* itself (with the sub-genera *Trimerocephalus*, *Phacops* proper, *Acaste*, *Pterygometopus*, *Chasmops*, *Dalmanites*, and *Cryphæus*) constitutes the entire family, and ranges from low down in the Ordovician series to the Upper Devonian rocks.

As regards the sub-genera of *Phacops*, *Trimerocephalus* includes Silurian and Devonian forms, in which the glabella is tumid in front (fig. 402, B); the glabella-furrows are faint or wanting; and the pygidium is of small size. In *Phacops* proper (fig. 402, A) the genal angles of the head-shield are rounded; the two anterior pairs of glabella-furrows are inconspicuous, and the glabella is very wide in front; the pleuræ are rounded; and the pygidium is of few segments, with an entire margin.

The species included under this head are Silurian and Devonian. *Dalmanites* (or *Dalmania*) includes forms with the pleuræ pointed and bent backwards, the pygidium being conspicuously segmented, and often ending in a spine (fig. 403). There are three glabella-furrows on each side, and the genal angles of the head-shield are long and produced. The species of this group are principally Silurian, but some of the forms are Ordovician and others are Devonian. *Chasmops* includes Ordovician species in which the genal angles are produced; the anterior glabella-lobes are laterally extended; the pleuræ have truncated ends; and the pygidium is of large size. *Pterygometopus* also includes Ordovician species, in which the frontal lobes of the glabella are laterally extended, and are intersected by the facial sutures. In *Acaste* are comprised Ordovician and Silurian species in which the glabella is not tumid, and exhibits all its furrows in a well-developed form, while the pygidium is often pointed. Lastly, *Cryphæus* includes Devonian types, and is principally distinguished by the fact that the margin of the pygidium is toothed or serrated.

Family 17. Proetidæ.—In this family the body is oval, distinctly trilobed, and capable of being rolled up. The head is of variable size, semicircular, sometimes with rounded, sometimes with spinose genal angles. The glabella is distinctly marked off from the cheeks, and the hindmost pair of glabella-furrows commonly circumscribe a basal lobe. The facial sutures cut the anterior margin of the head-shield separately. There are from eight to twenty-two body-rings, with grooved pleuræ, and the pygidium is distinctly segmented, and usually has an entire margin. The eyes have distinct facets, but are covered by a smooth cornea.

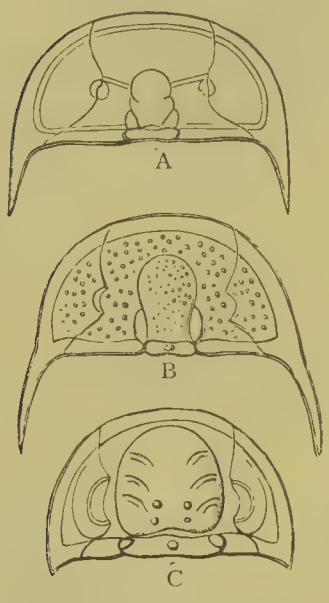


Fig. 404.—A, Head-shield of *Arethusina Koninckı*; B, Head-shield of *Cyphaspis Burmeisteri*; C, Head-shield of *Proetus Bohemicus*. From the Silurian rocks of Bohemia. (After Barrande.)

In *Proetus* itself (fig. 404, C) the head-shield is semicircular; the glabella has three pairs of lateral furrows; the eyes are large, semicircular, of numerous facets, covered by a thin cornea; there are eight or ten body-rings, and the tail has an "entire" border. The genus ranges from the Ordovician to the Carboniferous. *Cyphaspis* (fig. 404, B), of the Ordovician, Silurian, and Devonian rocks, differs from the preceding chiefly in its more convex glabella, with circumscribed basal lobes, its ovoid and remote eyes, and the generally greater number (fifteen to seventeen) of the body-rings. *Arethusina* (fig. 404, A), with a similar range in time, has its glabella much shortened, while the body-rings are as

many as twenty-two in number. *Carmon* is an Ordovician genus allied to *Proetus*, but it has neither eyes nor facial sutures, and it possesses eleven body-rings. The genus *Harpides* (apparently = *Erinnys* of Salter) is an interesting type, which appears to be intermediate between the *Proetidæ* and *Olenidæ*, and which carries back the range of the former into the Upper Cambrian. It has the "limb" of the head-shield very wide, and covered with a network of radiating and bifurcated nervures. On the other hand, the *Proetidæ* are represented in the Carboniferous rocks, not only by *Proetus* itself, but also by the genera *Phillipsia*, *Griffithides*, and *Brachymetopus*, one species of the first of these genera having been detected in deposits of Permian age. These types are therefore the most modern examples of the order *Trilobita* at present

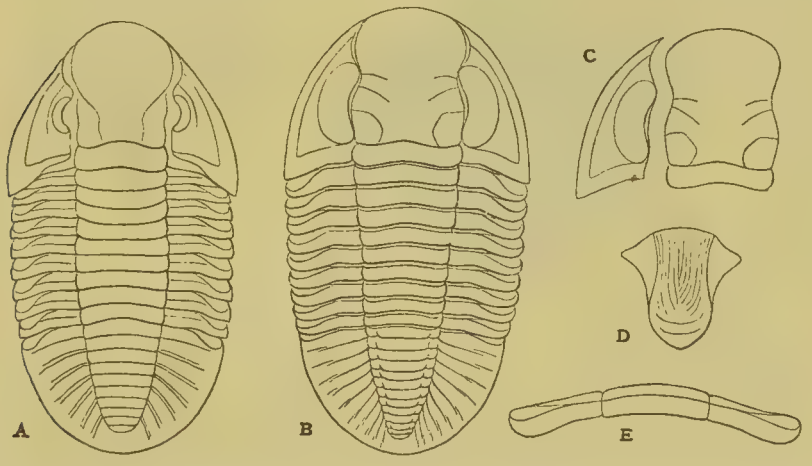


Fig. 405.—A, *Griffithides globiceps*, from the Carboniferous Limestone; B, *Phillipsia Derbiensis*, from the Carboniferous Limestone; C, Glabella and free cheek of the same; D, Hypostome of the same; E, Body-ring of the same. All the figures are enlarged. (After Henry Woodward.)

known to us. In the genus *Phillipsia* (fig. 405, B–E) the body is oval in form, and can be rolled up. The glabella (fig. 405, C) has nearly parallel sides, with two or three lateral furrows, the hindmost of which circumscribe a nearly circular basal lobe on each side. There are only nine body-rings. The tail is semi-oval, distinctly segmented, and with an "entire" margin; and the eyes are large, reticulated, and reniform. *Griffithides* (fig. 405, A) resembles *Phillipsia* in having nine body-rings, but the glabella is pyriform, without lateral furrows, and with the basal lobes inflated, while the eyes are small, lunate, and smooth. *Brachymetopus*, finally, much resembles the preceding in form, but the glabella is small, with lateral furrows but with no basal lobes. The eyes are small and smooth, and no facial sutures are visible. The head-shield is covered with a "small bead-like ornamentation" (Henry Wood-

ward). The thorax is unknown, but the pygidium is large, and the segments of the axis are beaded.

Family 18. Trinucleidæ.—In this singular family (fig. 406) the head-shield is enormously developed, with a wide margin or "limb," which is usually perforated by rounded pores. The glabella is well marked, but eyes are usually wanting, and the facial sutures may be absent. The body-rings are reduced to five or six in number, with grooved pleuræ; and the tail is wide and sub-triangular. The family contains three principal genera, viz., *Trinucleus*, *Dionide*, and *Ampyx*, all of which are Ordovician or Silurian in their range; and its zoological affinities seem to be with the *Harpedidæ*. In the well-known and widely-distributed genus *Trinucleus* (figs. 406, 407) the body is distinctly trilobed; the "limb" of the head-shield is

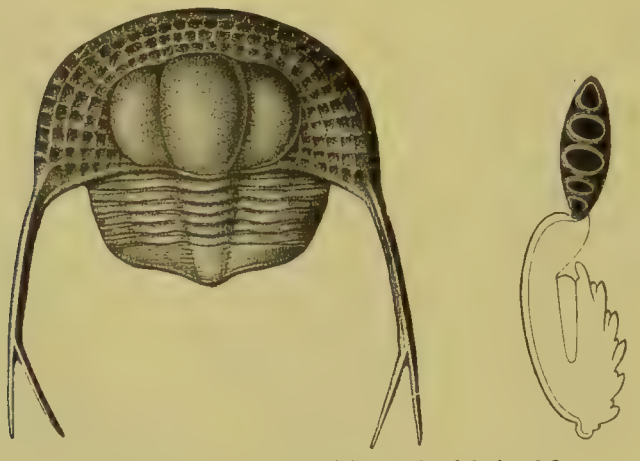


Fig. 406.—*Trinucleus Pongerardi*—Ordovician. The right-hand figure represents a vertical section of a rolled-up specimen.

composed of two lamellæ, and is perforated by numerous larger or smaller foramina; and the "genal angles" are prolonged into conspicuous spines which are usually single, but are forked in *T. Pongerardi*. The glabella is prominent and pyriform, with mere traces of lateral grooves, the facial sutures being rudimentary, and the cheeks being tumid, and generally furnished on each side with a small tubercle seemingly representing the eyes. There are six body-rings; and the tail is triangular, with a distinct axis, and having its margin entire and striated. The genus *Trinucleus* is wholly confined to the Ordovician rocks, and is specially characteristic of the Bala beds. The genus *Dionide* has a sub-quadrangular glabella; and the "limb" of the head-shield, though perforated, is rudimentary, and by absence of the facial sutures becomes continuous with the cheeks. The eyes are wanting, and there are six body-rings. In the curious Ordovician and Silurian genus *Ampyx* (fig. 408) the head is sub-triangular,

with spinose genal angles, and without a perforated "limb." The glabella is prolonged forwards in front of the head-shield as a triangular process, which is often extended into a long spine, while its lateral grooves are obsolete, and eyes are wholly wanting. The facial sutures are present and are discontinuous. There are five or six body-rings, and the tail is sub-triangular. The species of *Ampyx*

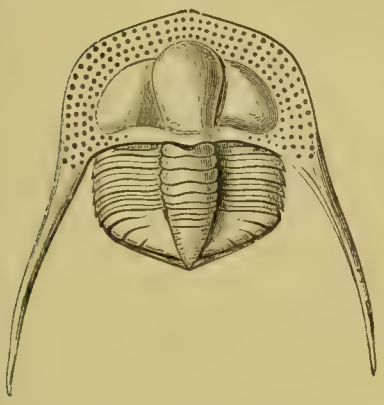


Fig. 407.—*Trinucleus concentricus*. Ordovician. (After Salter.)

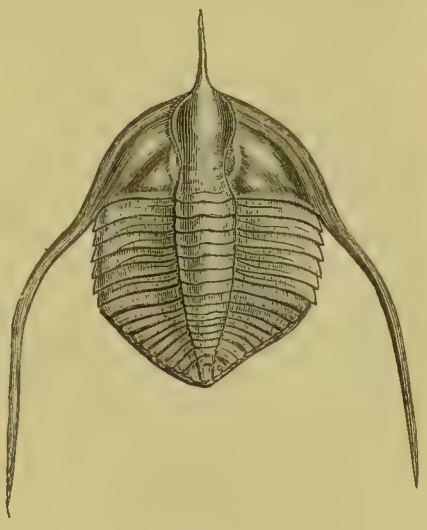


Fig. 408.—*Ampyx nudus*. Ordovician. (After Salter.)

are mostly Ordovician, but a few Silurian forms are known. *Endymionia* (Ordovician) is allied to both *Trinucleus* and *Ampyx*, but wants the perforated border of the former, and the prolonged glabella and genal spines of the latter.

Family 19.—Agnostidæ.—This, the last, family of the Trilobites includes a number of small forms of this order, which range from the Upper Cambrian to near the summit of the Ordovician. The cephalic and caudal shields in this group are nearly equal, and are very similar to one another in form and markings. The thoracic segments are reduced to two only in number, with grooved pleuræ; and both eyes and facial sutures are totally wanting. The type-genus of the family is *Agnostus* itself (fig. 409), which is represented by numerous forms in the Upper Cambrian and Ordovician rocks. *Microdiscus* of the Upper Cambrian (sometimes placed in the *Trinucleidæ* or in the *Olenidæ*) agrees with *Agnostus* in its want of facial sutures and eyes, but it has four body-rings, and the axis of the tail is segmented. Lastly, the *Shumardia* of the Ordovician (Quebec Group) is like *Agnostus*,



Fig. 409.—*Agnostus princeps*. Upper Cambrian. (After Salter.)

but has both the axis and lateral lobes of the pygidium distinctly segmented.

Division C. Merostomata.

The members of this group are Crustaceans, often of gigantic size, in which the mouth is furnished with mandibles and maxillæ, the terminations of which become walking or swimming feet, and organs of prehension. Two orders are included under the *Merostomata*—viz., the recent King-crabs (*Xiphosura*) and the extinct Eurypterids. By Professor Claus these orders are regarded as forming a special division of Arthropods, with relationships to the *Arachnida*, to which he applies the name of *Gigantostraca*. Professor Ray Lankester has also shown that there are various remarkable features of relationship between *Limulus* and the Scorpions; and the same point has been brought out by Van Beneden from his researches into the development of the King-crabs. Moreover, the investigations of Mr Benjamin Peach would show that there are close and important relationships between the Scorpions and the Palæozoic group of the Eurypterids.

Order I. Xiphosura (Pœcilopoda). — This order includes *Crustacea in which the anterior segments are amalgamated to form a large cephalic buckler, upon the dorsal surface of which are placed the eyes* (when present). *On the under side of the head-shield is placed the mouth, which is furnished with a rudimentary metastoma, and is surrounded by six pairs of appendages, the bases of all but the first pair being modified to act as masticating organs. The segments behind the head-shield may be fused with one another, or may be more or less completely free; and they carry upon their under surface a series of lamellar appendages which are branchial in function. The last segment of the body forms a sword-like movable telson.*

The only existing genus contained in the order *Xiphosura* is *Limulus*, comprising the King-crabs or Horse-shoe Crabs. In this genus (fig. 410) the anterior segments—usually regarded as representing the head and thorax—are fused to form a horse-shoe-shaped cephalothoracic shield. The upper surface of this carries subcentrally a pair of large compound eyes, and also a pair of small larval eyes placed in the middle line in front. On the under side of the head-shield is the mouth, surrounded by six pairs of jointed limbs, the last five pairs having their basal joints spinose, and thus adapted to act as jaws. The first pair of appendages — often regarded as representing the antennæ—are placed in front of the mouth and terminate in nipping-claws. The next four pairs of appendages are also generally chelate, while each of the last pair of legs is terminated by two flat spines, with a whorl of similar spines proximally, being thus adapted for locomotion. Behind

the cephalic buckler comes a second, somewhat rhomboidal shield, the segments of which are immovably welded together, and which is usually regarded as representing the abdomen, though some authorities consider it as the thorax. The lateral margins of this abdominal shield carry movable spines, and on its under surface in front are placed the generative openings, protected by a broad, divided "operculum," which is formed by the first pair of abdominal limbs. The operculum not only covers the reproductive apertures, but more or less extensively conceals the remaining five pairs of abdominal limbs. These latter are much modified, and support a number of delicate lamellæ arranged like the leaves of a book, which act as branchiæ. Lastly, the abdominal shield has movably articulated to its hinder margin a long ensiform "telson" (fig. 410).

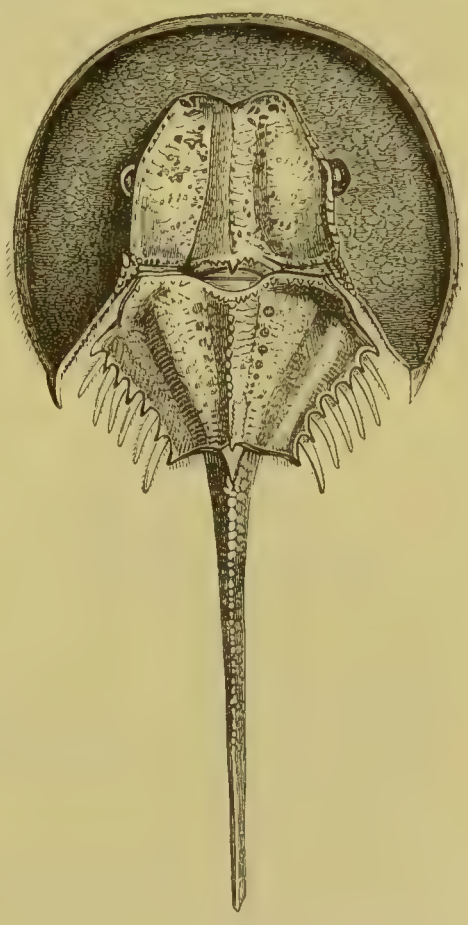


Fig. 410.—*Limulus moluccanus*, viewed from the dorsal aspect, and reduced in size. (Recent.)

The integument of *Limulus* is thoroughly hardened by the deposition of chitine, and forms a resisting shell. Thin sections show that this is largely composed of a peculiar finely tubulated tissue, which has very much the appearance of dentine under the microscope (fig. 411, A). In the inner layer of the shell, the minute tubuli just mentioned are accompanied by a limited number of vertical canals of larger size (fig. 411, A, *c*), the structure thus coming closely to resemble that shown in vertical sections of the shell of the Trilobites.

The embryo of *Limulus* (fig. 382) is destitute of the tail-spine of the adult, this structure only existing in a rudimentary form; and in this stage of its existence, as previously noticed, it bears a strong resemblance to certain of the Trilobites.

It is not necessary here to enter into the vexed question as to

whether *Limulus* should properly be placed among the *Crustacea* or the *Arachnida*. It is sufficient to note that the *Xiphosura* are clearly related to the Eurypterids on the one hand and the Trilobites on the other hand; and that when the natural systematic arrangement of the *Arthropoda* shall have been finally settled, these three orders will necessarily be placed close together. The *Xiphosura* and the *Eurypterida*, in particular, are closely connected together by means of *Hemiaspis* and its allies. So much so is this the case, that while Dr Henry Woodward places *Hemiaspis* and the genera related to it among the Eurypterids, these forms are placed by Zittel among the Xiphosurans, an arrangement which will be followed here.

The existing species of *Limulus* are aquatic in habit and are inhabitants of the sea. The oldest fossil types of the *Xiphosura*

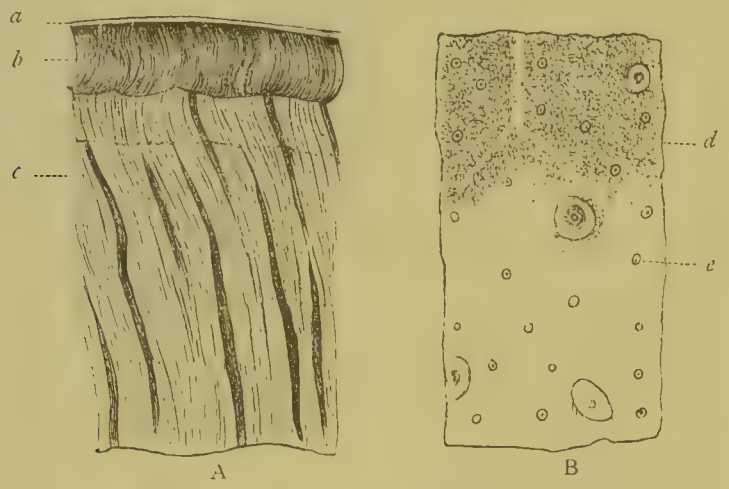


Fig. 411.—A, Part of a transverse section of the tail-spine of *Limulus*: *a*, Outer cuticular layer; *b*, Intermediate finely tubulated layer; *c*, Internal layer of finely tubulated tissue with interspersed larger tubes. B, Part of a tangential section of the inner layer of the cephalic buckler; *d*, Portion of the section showing the minute dots representing the transversely divided tubuli, together with the cut ends of the larger tubes, which are alone shown at *e*. (Original.)

(*Hemiaspis*, *Neolimulus*, &c.), appear in the Silurian rocks. Other ancient types of the order (*Belinurus* and *Prestwichia*) appear in the Carboniferous formation. The oldest types of *Limulus* itself are found in the Triassic rocks.

The *Xiphosura* are divided by Zittel into the two families of the *Hemiaspidæ* and the *Limulidæ*, the former including all the Palæozoic types of the order, while the genus *Limulus* alone is comprised in the latter. In the *Hemiaspidæ*, the cephalic shield is separated from the thorax, and sometimes possesses a "facial suture." The thorax[1] is composed of five or six segments which are usually free

[1] By Packard the head-shield of the *Hemiaspidæ* is regarded as representing the entire cephalothorax; and the free segments which immediately follow this are considered as belonging to the *abdomen* and not to the thorax.

(fig. 412); and the abdomen consists of three or more rings, and is terminated by a spine-like telson. The appendages are as yet unknown.

The genus *Hemiaspis* (fig. 412, A) comprises some singular Silurian Crustaceans, in which there is a semicircular head-shield with a central glabella, and indications of facial sutures and eyes. The thorax is trilobed, and consists of six free segments. There are three free segments in the abdomen, and these are followed by a long spiniform telson. The genus *Pseudoniscus*, also from the Silurian rocks, resembles *Hemiaspis* in many points, and particularly in the possession of free thoracic segments, but there is no distinct line of demarcation between the thorax and the abdomen (fig. 412, B). Another Silurian genus, also closely re-

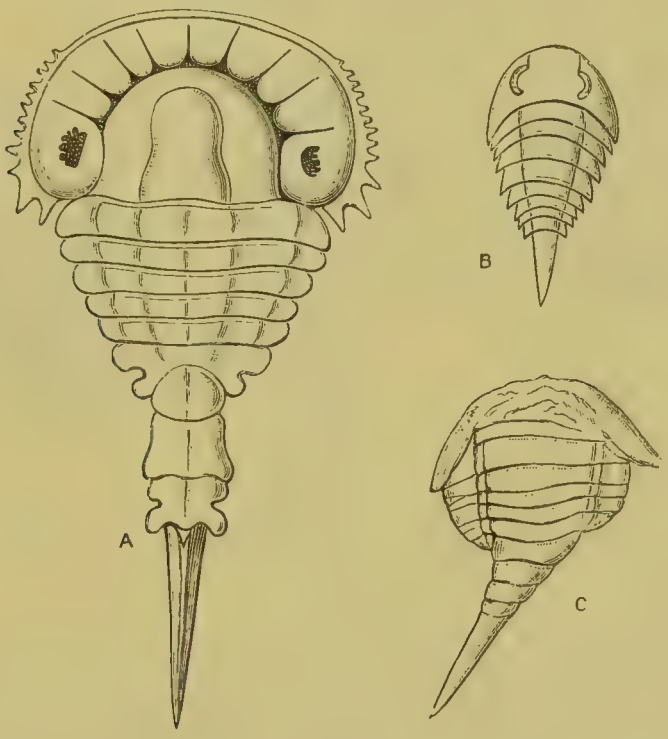


Fig. 412.—A, *Hemiaspis limuloides* (after H. Woodward); B, *Pseudoniscus aculeatus* (after Nieszkowski); C, *Bunodes* (*Exapinurus*) *Schrenkii* (after Nieszkowski). All from the Silurian.

lated to the preceding, is *Bunodes* (*Exapinurus*), in which the thorax likewise consists of free rings, but the last two are fused with one another. There are three movable abdominal rings and a spine-like telson (fig. 412, C), and the animal possessed, like so many of the Trilobites, the power of rolling itself into a ball.

In the remarkable genus described by Dr Henry Woodward from the Silurian rocks of Britain under the name of *Neolimulus* (fig. 413), the head-shield has a general resemblance to that of the recent *Limulus*, and there are traces of a divisional line crossing the head and apparently corresponding with the "facial suture" of the Trilobites. Compound eyes and ocelli seem to be present, and there are six free thoracic segments,

followed, probably, by three free abdominal rings, of which only two have been preserved. A long spiniform telson may be conjecturally added to complete this ancient Limuloid Crustacean. In the Devonian rocks, the only genus of Xiphosurans which has hitherto been recognised with certainty is the *Protolimulus* of Packard, which appears to be nearly related to *Neolimulus*. In the Carboniferous rocks, on the other hand, the Limuloids are represented by a number of forms, the most important genus being *Prestwichia* (fig. 414), which has the general form of *Neolimulus*, but in which the thoracic and abdominal segments are not marked off from one another, and are all anchylosed. The genus *Euproöps*, from the Coal-measures of North America, is hardly separable from the preceding, but the eyes are situated on the anterior edge of the

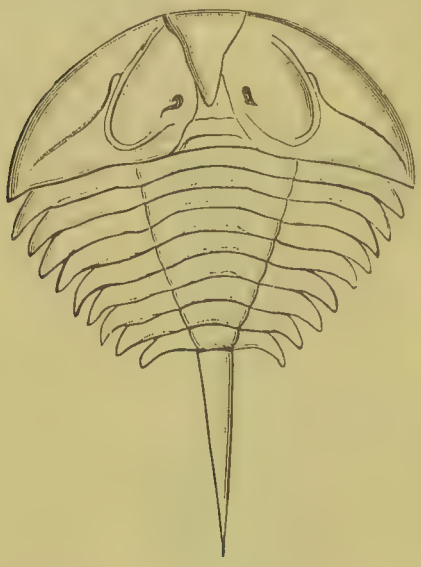


Fig. 413.—*Neolimulus falcatus*, enlarged about three times. Silurian. (After Henry Woodward.)

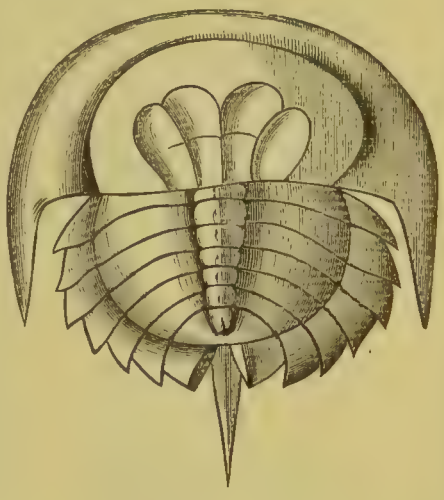


Fig. 414.—*Prestwichia rotundata*. Coal-measures.

cephalic buckler. Another well-known Carboniferous genus is *Belinurus*, which agrees with the preceding in having five thoracic and three abdominal segments, together with a long tail-spine, but in which the thoracic rings are free and movable, while those of the abdomen are anchylosed with one another. It would also seem probable that the singular Crustacean fossils which have been described from the Coal-measures under the name of *Cyclus*, are really, as maintained by Dr Henry Woodward, the young forms of such Carboniferous Xiphosurans as *Belinurus* and *Prestwichia*. The very similar Triassic fossils, for which the generic name of *Halycine* has been proposed, are probably also the larval forms of Limuloid Crustaceans.

The family of the *Limulidæ* is distinguished from that of the *Hemiaspidæ* by the fact that the cephalic and thoracic segments are amalgamated to form a cephalothoracic shield, the upper surface of which bears two compound eyes and a pair of simple eyes. The abdominal segments are amalgamated with one another to form a

second post-cephalic shield, which is terminated by the movable, spine-like telson. The only genus of this family is *Limulus* itself, the characters of which have been already treated of in some detail. The earliest undoubted fossil species of *Limulus* appear in the Trias of Europe, and other representatives of the genus are found in the Jurassic rocks (the Lithographic Slates of Germany), and in the

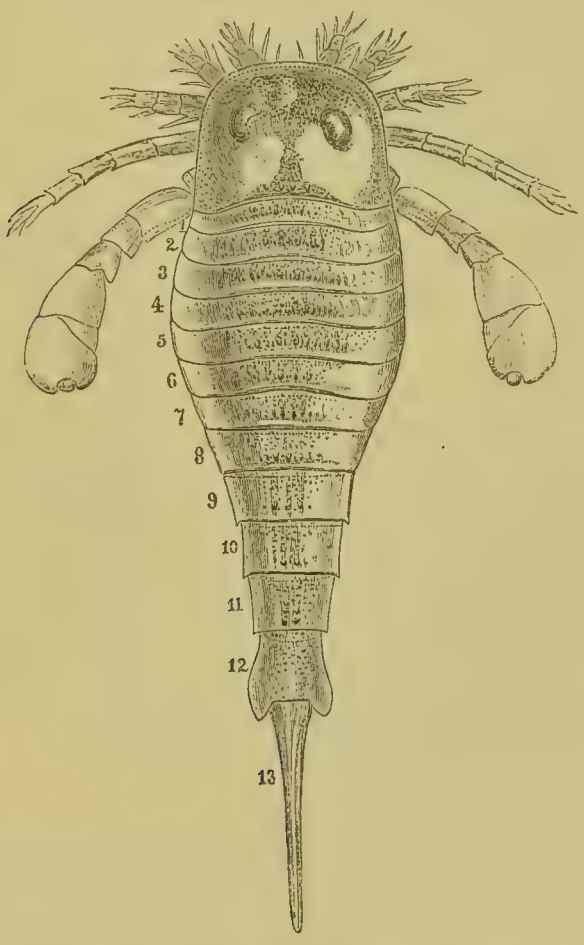


Fig. 415.—*Eurypterus Fischeri*, from the Silurian rocks of Oesel, viewed from above and restored, the size being about one-fifth of nature. The segments behind the carapace are numbered, the first six being sometimes considered as thoracic. (After Friedrich Schmidt. Copied from Zittel.)

Cretaceous and Tertiary deposits. Of the existing species of the genus, one is found on the east coast of North America, and others occur on the eastern shores of Asia and in the Malayan Archipelago.

Order II. Eurypterida.—The Eurypterids are *large Crustaceans* (fig. 415), *in which the body is elongated and compressed, and the chitinous integument is ornamented with a characteristic scale-like*

sculpturing. The anterior part of the body is covered with a carapace, which carries a pair of large, marginal, or subcentral eyes, and a pair of small ocelli placed near the centre. On the under side of the carapace is the opening of the mouth, furnished behind with a large undivided metastoma and with a series of jointed appendages (five or six pairs in number), of which the first are præoral, and represent antennæ, while the remainder are modified for mastication or locomotion, the last pair forming usually great swimming-feet. Behind the carapace the body consists of numerous free thoracico-abdominal segments, certain of the anterior of which are furnished below with divided lamellæ, which concealed the branchiæ. The hinder segments carry no appendages, and the abdomen terminates in a spine-like or paddle-shaped telson.

The integument of the Eurypterids is hardened by chitine, and when transparent fragments are examined under the microscope, these exhibit a reticulated structure, numerous clear rounded corpuscles, of various sizes, appearing to be disseminated in a horny matrix; the crust thus assuming a punctated or porous aspect. The characteristic "scale-marking" is the result of the development at intervals of curved linear thickenings of the exoskeleton.

The anterior part of the body in the Eurypterids is covered by a comparatively short, semicircular, or subquadrate carapace, which is considered by Woodward, Schmidt, and Zittel as representing the head only, but which is regarded by Claus and Hall as a cephalothorax. The upper surface of the carapace carries a pair of large, prominent, faceted, compound eyes, which may be subcentral, or may be placed on the margin of the head-shield. There is also a pair of small ocelli, usually placed close together, subcentrally.

On the under side of the carapace is the opening of the mouth, surrounded by a series of jointed appendages. The first pair of appendages (fig. 416, *an*) are præoral in position, and represent the antennæ. They terminate in pincers in *Pterygotus* (fig. 416, *an*), but are stated by Fr. Schmidt to have the form of very slender jointed organs in *Eurypterus*. The remaining appendages are similar to those of *Limulus* in having their bases spinous, and in officiating as jaws. Woodward recognises four pairs of these; but according to Fr. Schmidt there are five pairs, the total number of appendages on the under side of the head-shield being thus six pairs. The anterior appendages behind the antennæ may represent mandibles and maxillæ, and they have the form of slender jointed organs, with dilated and serrated basal joints (fig. 416, *gn*). The last pair of appendages, regarded by Woodward as maxillipedes (fig. 416, *mx*), are of great size, and while their bases are dentated to fit them for mastication, they are usually dilated distally so as to form powerful swimming-paddles. The mouth is a longitudinal

fissure on the under side of the head, surrounded by the toothed bases of the limbs, and provided behind with a large undivided metastoma (fig. 416, *m*), while in some cases a hypostome or upper lip appears to be present as well.

Behind the carapace the body consists of thirteen free segments, counting the telson as one. By Claus and Hall the whole of these segments are regarded as belonging to the abdomen. By other

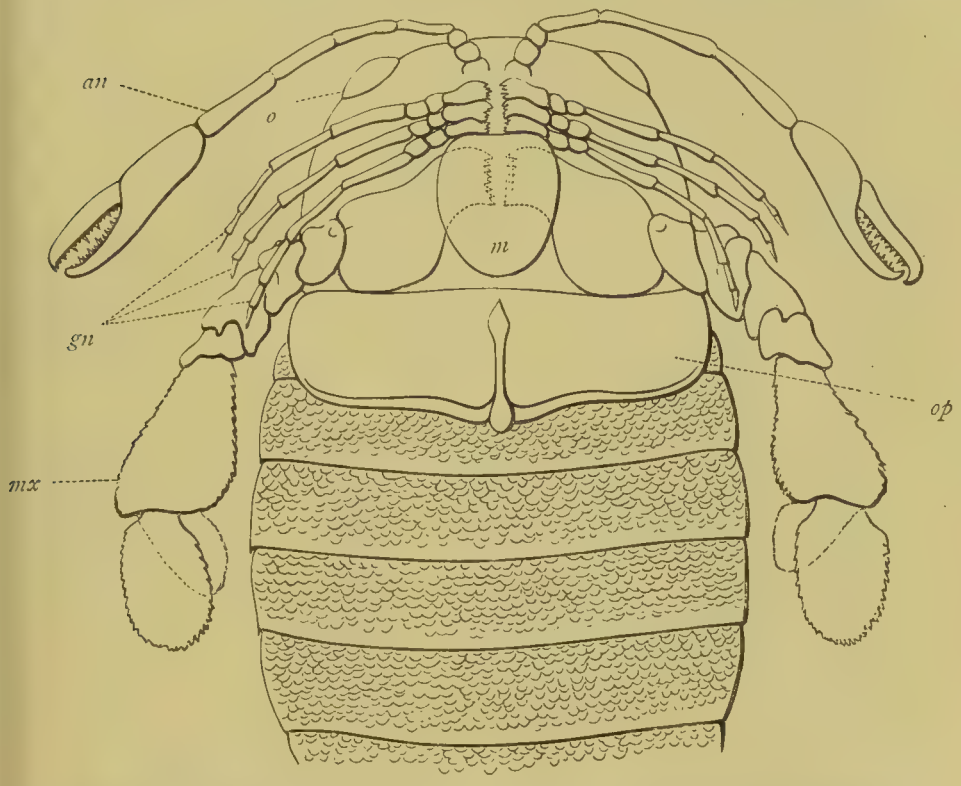


Fig. 416.—Under side of the head and the following segments of *Pterygotus Anglicus*, restored. *o*, The large compound marginal eyes; *an*, The first pair of appendages, chelate, and representing antennæ; *gn*, Three pairs of slender "gnathopods," with spinose bases, placed on the sides of the mouth-opening (according to Fr. Schmidt, there are *four* pairs of these organs); *mx*, the last pair of appendages ("maxillipedes"), developed into great swimming-feet, but acting by their bases as jaws; *m*, Metastoma, drawn as if it were transparent, so as to show the toothed bases of the last pair of appendages below it; *op*, Operculum. The "scale-marking" is only represented on the segments behind the operculum. (After Henry Woodward.)

authorities, however—as, for example, by Fr. Schmidt—the anterior six of these segments are regarded as belonging to the thorax, while the posterior seven are looked upon as forming the abdomen. Immediately behind the carapace, on the inferior aspect of the body, is a broad lamellar plate, which is divided into two lateral halves by a narrow median process (fig. 416, *op*), and which is known as the "operculum." This plate, like the structure which bears the same name in the King-crabs, doubtless protected the openings of the

reproductive organs, and also served to conceal the leaf-like gills, fragments of which are sometimes found in the fossil state. According to Fr. Schmidt, the segments immediately following the "operculum" have their ventral side formed, each, by a pair of lamellar plates, which meet in the middle line, and which are regarded by this observer as modified thoracic appendages carrying branchiæ. According to the investigations of Mr Benjamin Peach, some Eurypterids were further provided with well-developed pectinated organs, apparently similar in form and structure to the so-called "combs" (*pectines*) of the existing Scorpions. Lastly, the seven hindmost segments of the body are undoubtedly devoid of appendages of any kind, and the last of these is the "telson." The form of this varies, being lanceolate or bilobate in *Pterygotus* and *Slimonia*, but narrow and sword-shaped in *Eurypterus* and *Stylonurus*.

There are at present no materials available for working out the development of the Eurypterids, but there is every reason to suppose that the berry-like bodies which are found in the Old Red Sandstone of Scotland, and which have been described under the name of *Parka decipiens*, are really the eggs of Crustaceans belonging to this order.

There can be no question as to the importance of the relationships between the Eurypterids and the Scorpions; and many high authorities consider that the order *Eurypterida* should be removed from the *Crustacea* and placed in the series of the *Arachnida*. There is, however, no reason for doubting that the Eurypterids were water-breathing animals, provided with branchiæ; and as the nature of the respiratory organs constitutes, perhaps, the most weighty of the distinctions between the closely related classes of the *Crustacea* and the *Arachnida*, it would seem proper to regard the *Eurypterida* as an ancient type of the *Crustacea*, in which are preserved certain of the characters which must have been possessed by the ancestral Arthropods from which these two classes originally diverged.

The nature of the deposits in which the remains of Eurypterids are found, and of the fossils associated with them, would prove that these animals were essentially marine, their habits, probably, being very similar to those of the existing King-crabs. It is, however, possible that certain of the Eurypterids were inhabitants of brackish, or even of purely fresh, waters. As regards their geological range, the Eurypterids seem to have appeared for the first time in the Ordovician rocks, but comparatively little is known of the early representatives of the order. On the other hand, Eurypterids abound in the Silurian rocks, and it is in this system of deposits that the order seems to have attained its maximum development. Numerous Devonian Eurypterids are also known, and the genus *Eurypterus* is represented in the Carboniferous rocks, while a doubtful repre-

sentative of the order (*Campylocephalus*) has been recorded from the Permian rocks of Russia. With the close of the Palæozoic period, however, the order appears to have undergone complete extinction.

The four most important genera of the Eurypterids are *Eurypterus*, *Pterygotus*, *Slimonia*, and *Stylonurus*. In *Eurypterus* (fig. 415) there are five pairs of legs attached to the under surface of the head-shield, all of which have their bases modified to act as masticatory organs, and the last pair of which are developed into powerful swimming-paddles. There is also, according to Fr. Schmidt, an additional, præoral pair of appendages, in the form of delicate jointed filaments, which represent the antennæ but are not chelate. Most of the species of *Eurypterus* are found in the highest deposits of the Silurian rocks ; but there are a few Devonian species, and the Carboniferous rocks have likewise yielded representatives of the genus (*e.g.*, the *E. Scouleri* of the Scotch Carboniferous rocks).

The genus *Pterygotus* (fig. 416) is principally Silurian and Devonian, the largest species (*Pterygotus Anglicus*)—sometimes attaining a length of nearly six feet—being found in the Old Red Sandstone of Scotland ; but Barrande has described forms of the genus from the Ordovician rocks of Bohemia. *Pterygotus* differs from *Eurypterus*, among other characters, in the marginal position of the large compound eyes, and in the fact that the præoral appendages (antennæ) are very long and terminate in nipping-claws. The telson of *Pterygotus*, further, is broad and lanceolate, whereas that of *Eurypterus* is long and pointed. The Silurian genus *Slimonia* resembles *Pterygotus* in the form of the telson and in the marginal position of the compound eyes, but differs from it in the quadrate form of the head-shield and in the structure of the limbs. Finally, the Silurian and Devonian genus *Stylonurus* resembles *Eurypterus* in the possession of an ensiform telson, and in its general structure ; but the last two pairs of limbs are developed into long slender rowing-organs, which reach nearly to the hinder extremity of the body.

CHAPTER XXX.

CRUSTACEA—continued.

Sub-class III.—Malacostraca.

The Crustaceans included in the sub-class *Malacostraca* (*Thoracipoda*, Woodward) are distinguished by the possession of a generally *definite* number of body-segments; seven somites going to make up the thorax, and an equal number entering into the composition of the abdomen (counting, that is, the telson as a somite). The *Malacostraca* are divided into two primary divisions, termed respectively the *Hedriophthalmata* and the *Podophthalmata*, according as the eyes are sessile or are supported upon eye-stalks.

Division A. Hedriophthalmata.

This division comprises those *Malacostraca* in which the eyes are sessile, and the body is mostly not protected by a carapace. It comprises the two orders of the *Isopoda* and *Amphipoda*. The eyes are generally compound, but sometimes simple, and are placed on the sides of the head. The head is almost always distinct from the thorax, and the mandibles are often furnished with a palp. Typically there are seven pairs of feet in the adult, hence this division has been called *Tetradecapoda* by Agassiz.

Order I. Amphipoda.—The members of this order are Crustaceans, mostly of small size, in which *the body is laterally compressed, and the thorax consists of seven segments, carrying seven pairs of legs. The abdomen is mostly well developed, and consists of seven segments. The gills are lamellar or vesicular, and are attached to the basal joints of the thoracic legs. The seven pairs of thoracic limbs are directed partly forwards and partly backwards.* It is from this latter circumstance that the name of the order is derived.

The order of the Amphipods comprises both marine and fresh-water forms, many familiar types, such as the Sand-hoppers (*Talit-*

rus) and Shore-hoppers (*Orchestia*), being more or less amphibious in habit, while some genera (such as *Gammarus*) possess both marine and fresh-water representatives. The geological history of the Amphipods is still very imperfectly known. If the incompletely understood Palæozoic genera *Gampsonyx*, *Palæocaris*, *Palæorchestia*,

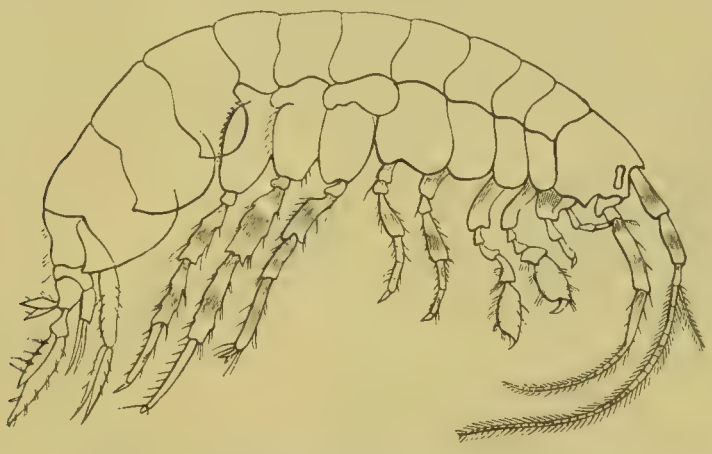


Fig. 417.—*Gammarus locusta*, enlarged about four times. Recent. (After Spence Bate and Westwood).

and the forms allied to these, be excluded from the order, the number of known fossil forms of the order is very small. If the genus *Necrogammarus* described by Dr Henry Woodward from the Silurian rocks of Britain, be truly referable here, it is the oldest type of the Amphipods at present known. Hardly less certain is the position of the Permian genus *Prosoponiscus* (*Palæocrangon*),

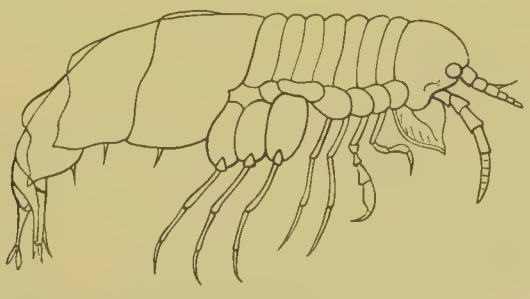


Fig. 418.—*Prosoponiscus* (*Palæocrangon*) *problematicus*, viewed from one side, and partially restored. From the Magnesian Limestone (Permian) of Durham. (After Spence Bate.)

which Mr Spence Bate has described as related to the living *Phædra antiqua*. The fossil forms of the *Amphipoda* from the Tertiary series are almost exclusively from fresh-water deposits, and either belong to such existing genera as *Gammarus* or are nearly allied to other living types. No fossil representatives of the little group

of parasitic Amphipods included under the name of *Læmodipoda* have been as yet discovered.

Order II. Isopoda.—In this order *the head is always distinct from the segment bearing the first pair of feet. The respiratory organs are not thoracic*, as in the preceding order, *but are attached to the inferior surface of the abdomen, and consist of leaf-like branchiæ, which in the terrestrial species are protected by plates which fold over them. The thorax is composed of seven segments, bearing typically seven pairs of limbs*, which, in the females, have marginal plates, attached to their bases, and serving to protect the ova. The num-

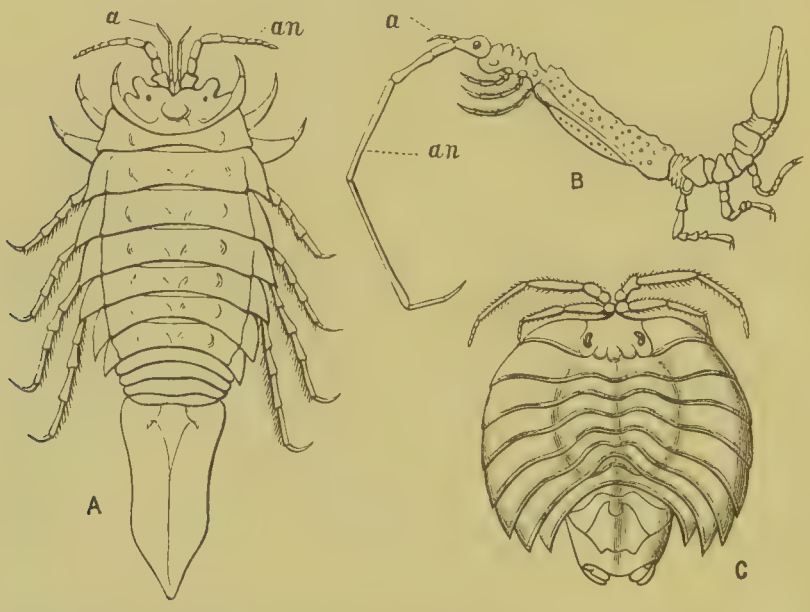


Fig. 419.—Recent Isopoda. A, *Idotea entomon*, enlarged; B, *Arcturus longicornis*, enlarged; C, *Serolis Scythei*: *an*, Antennæ; *a*, Antennules. (After Gerstaecker, Spence Bate and Westwood, and Lütken.)

ber of segments in the abdomen varies, but is never more than seven. The abdominal segments are in many Isopods coalescent, and form a broad caudal shield, beneath which the branchiæ are carried (fig. 419, A).

The recent Isopods are for the most part of small size, and are of the most varied habit. Many forms are strictly marine, some forms occurring even at great depths (over 2000 fathoms), but very many types are either inhabitants of shallow water or live between tide-marks. Some forms, such as the *Bopyridæ*, are parasitic in the adult condition. Many Isopods live in fresh waters, some of these belonging to genera which are also represented by marine forms. Other Isopods, like the Wood-lice (*Oniscidæ*) are terrestrial in habit.

As in the case of the Amphipods, the geological history of the Isopods is very imperfectly known. The Palæozoic Arthropods which have been referred here, such as the problematical *Arthropleura* of the Carboniferous rocks, and the form described by Dr Henry Woodward from the Old Red Sandstone under the name of *Prærarcturus*, are of doubtful affinities. The earliest unquestionable Isopods are found in the Jurassic rocks (the Lithographic Slates of Germany), in which the order is represented by the extinct genera *Urda* and *Ægites*. In the Upper Jurassic (Purbeck beds) of Britain is found the *Archæoniscus Brodiei* (fig. 420), often in considerable numbers, the genus being apparently referable to the recent family of the *Ægidæ*. To the same family belongs the extinct genus *Palæga*, species of which are found in the Cretaceous and Tertiary rocks. A tolerably abundant Tertiary genus is *Eosphæroma*, which belongs to the recent family of the *Sphæromidæ*. Lastly, the terrestrial family of the Wood-lice (*Oniscidæ*) is represented in late Tertiary deposits by such existing genera as *Armadillo*, *Porcellio*, and *Oniscus* itself.

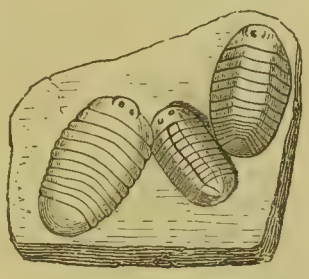


Fig. 420.—*Archæoniscus Brodiei*, a fossil Isopod from the Purbeck Beds.

Division B. Thoracostraca or Podophthalmata.

The Crustaceans included in this division possess compound eyes which are usually placed upon movable peduncles; while the anterior part of the body is covered with a "carapace" or shield, which covers the head and the anterior thoracic segments at any rate, and often protects the entire cephalothorax. The body consists of nineteen undoubted segments, of which thirteen belong to the cephalothorax and six to the abdomen. If the ocular ring and the telson be counted as segments, there are then twenty-one segments altogether. All of the *Thoracostraca* except certain of the Shrimps (*Penæidæ*) pass through "Zoea" stages in their development. The division *Thoracostraca* comprises the four orders of the *Cumacea*, the *Schizopoda*, the *Stomatopoda*, and the *Decapoda*, of which the last includes the most highly organised and familiar examples of the class *Crustacea*. Of these orders, the first two have no direct fossil representatives, though we may consider in connection with the Schizopods certain Palæozoic Crustaceans, which are possibly ancestral types of the order. The Stomatopods are represented by few fossil forms, beginning, perhaps, in the Carboniferous rocks. On the other hand, there are numerous known fossil forms of the

Decapod Crustaceans, especially in the Mesozoic and Tertiary deposits; but the palæontological interest of these is comparatively small, and it will be sufficient here to give a brief sketch of the general geological history of the three great tribes into which the order *Decapoda* is divided.

Order I. Cumacea.—This order includes small marine Crustaceans, in which there is *a short carapace covering the head and the anterior thoracic segments. The eyes are sessile, and the mouth-organs resemble those of the Isopoda. The two anterior pairs of legs at least possess natatory exopodites, and the branchiæ are attached to the epipodites of the maxillipedes. The abdomen is elongated and composed of six segments, and a telson may be present or absent.*

The *Cumacea* are regarded by G. O. Sars as an order of *Crustacea* related on the one hand to the Schizopods or Macrurous Decapods, and on the other hand to the *Isopoda*. No fossil forms of the order are known.

Order II. Schizopoda.—This order includes the "Opossum Shrimps" (*Mysis*) and their allies, comprising small Crustaceans which are in many respects related to the *Decapoda*. According to G. O. Sars, the Schizopods occupy "the most primitive position

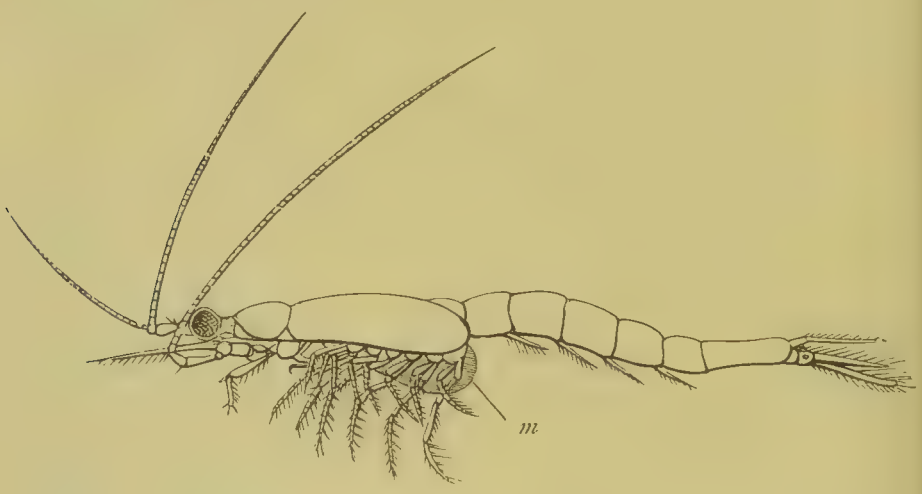


Fig. 421.—"Opossum Shrimp" (*Mysis oculata*). *m*, Marsupial pouch. (After G. O. Sars.)

within the division *Podophthalmia*, being apparently the least modified forms, in which the original characters distinguishing the progenitors of the whole division would seem to exhibit least change." The correctness of this view is shown by the fact that many of the Podophthalmate Crustaceans pass in their development through a "Mysis-stage," in which they present marked Schizopodous characters. The Schizopods are characterised by the fact that *the*

thoracic limbs are eight on each side, and are provided each with an exopodite and endopodite (fig. 421), *the exopodites being natatory in function. A cephalothoracic shield is present, and there is usually only a single pair of maxillipedes. The gills are attached to the thoracic legs, or, exceptionally, to the abdominal feet. The ova are carried beneath the thorax of the female, usually in a marsupial pouch formed by leaf-like plates produced from the bases of the legs* (fig. 421, *m*). *The telson often possesses minute terminal appendages or spines.*

The Schizopods are distinguished from the Decapods by the larger number of the thoracic limbs, and by the fact that these appendages have well-developed exopodites, as well as by the fact that the gills are not carried in branchial chambers formed by a downward prolongation of the sides of the carapace. In *Mysis* and its allies true branchiæ are wanting. With the single exception of the *Mysis relicta* of the great lakes of Sweden and North America, all the Schizopods are inhabitants of the sea, extending their range to considerable depths.

No undoubted fossil forms of the *Schizopoda* are as yet known, but a brief consideration may be given here to the singular Palæozoic genera *Palæocaris* and *Gampsonyx*, which some authorities regard as aberrant members of the *Amphipoda*, but which are considered by Packard as being probably ancestral types of the Schizopods. The genus *Palæocaris* (fig. 422) includes peculiar elongated Crustaceans from the Coal-measures of North America and Britain, in which there is a short cephalothoracic shield, but the hinder thoracic segments are free. There are two pairs of antennæ, of nearly equal length, and the limbs do not appear to be bifid. The telson has a pair of "stylets" on each side, and the condition of the eyes has not been clearly ascertained. The genus *Acanthotelson*, also from the Coal-measures, appears to be related to *Palæocaris*, as, possibly, are the genera *Palæorchestia* (Carboniferous) and *Nectotelson* (Permian), but the true relationships of these forms are very uncertain. Another Carboniferous genus which may perhaps find a place here is *Gampsonyx*, including small Crustaceans which have a general resemblance to the Amphipods in appearance, but in which the limbs seem to have been of the Schizopodous type.

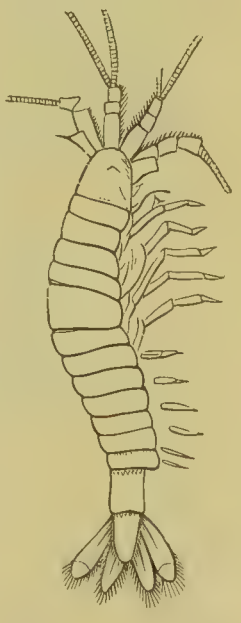


Fig. 422. — *Palæocaris typus*, slightly enlarged. From the Coal-measures of North America. (After Meek and Worthen.)

Order III. Stomatopoda.—This order includes the recent

Locust-shrimps (*Squilla*), all of which are inhabitants of the sea. The Crustaceans of this order (fig. 423) have *a short cephalothoracic carapace, which does not protect the hinder segments of the thorax. There are five pairs of maxillipedes, and three pairs of thoracic legs. The branchiæ are not enclosed in a cephalothoracic gill-chamber on each side, but are in the form of tufts attached to the abdominal feet. The eyes and antennæ are attached to a somite which is not soldered to the cephalothorax.*

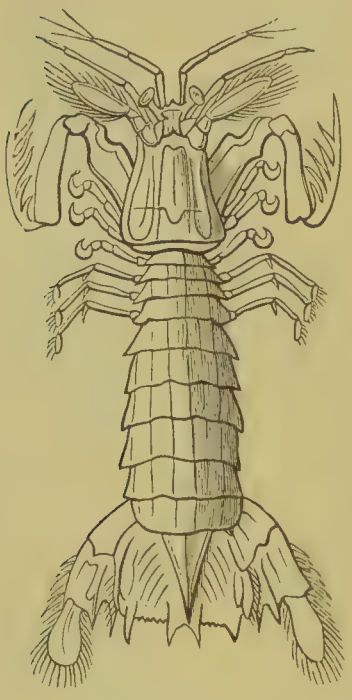


Fig. 423.—*Squilla mantis*, the Locust-shrimp.

As regards their distribution in time, it is doubtful if any Palæozoic types of the Crustacea can be referred to this order, but the genera *Necroscilla* and *Diplostylus*, of the Coal-measures, may possibly be ancient representatives of the *Stomatopoda*. In the Jurassic rocks (Lithographic Slates) of Germany is found the genus *Sculda*, which is related to the recent genus *Squilla*, and species of the latter have been described from the Cretaceous rocks, while others occur in the Eocene Tertiary.

Order IV. Decapoda.—This order includes the Shrimps and Lobsters, the Hermit-crabs, and the true Crabs, and comprises the most highly organised of all the *Crustacea*. Most of the Decapods are aquatic in their habits, and they are usually protected by strong resisting shells. There is always a complicated set of "gnathites," or appendages modified for masticatory purposes, surrounding the mouth. *The ambulatory feet are made up of five pairs of legs* (hence the name of the order); *the first pair—and often some other pairs behind this—being "chelate," or having their extremities developed into nipping-claws. The branchiæ are pyramidal, and are contained in cavities at the side of the thorax. The carapace is well developed, and covers all the segments of the head and thorax.*

The *Decapoda* are divided into three tribes, termed respectively the *Macrura*, *Anomura*, and *Brachyura*, and characterised by the nature of the abdomen.

Tribe A. Macrura. — This tribe includes the "Long-tailed Decapods," such as the Lobsters, Cray-fish, Shrimps, and Prawns, in which the abdomen is well developed, often longer than the

cephalothorax, and its posterior extremity is in the form of a powerful natatory organ or caudal fin. The recent Macrurans are mostly marine in habit, but some typical forms (the Cray-fishes) are inhabitants of fresh water. The earliest fossil representatives of the *Macrura* are certain Shrimp-like Crustaceans which appear in the Devonian and Carboniferous rocks, but the group undergoes a great development in the Mesozoic period, and many Tertiary forms are known as well. It will be sufficient here to give a general sketch of the geological history of the group, without discussing its different families in any detailed manner.

The oldest known Macruran is the Shrimp-like *Palæopalæmon* of the Devonian rocks of North America, the general characters of which would justify its reference to the existing family of the Shrimps and Prawns (*Caridida*). To the same family may be referred the Carboniferous genera *Anthrapalæmon* (fig. 425), *Crangopsis*, and *Pygocephalus*. In *Anthrapalæmon*, there is a well-developed carapace, which is furnished with a beak or "rostrum," and possesses serrated lateral margins. There are five pairs of thoracic legs; the abdomen is composed of free segments, and there is a caudal fin, formed by the telson along with the last pair of swimmerets. No undoubted representatives of the *Macrura* have hitherto been detected in the Permian rocks, but the Trias has yielded a number of Long-tailed Decapods belonging to the families of the Shrimps (*Penæus* and *Æger*), the *Eryonidæ*, and the *Glyphæidæ* (*Pemphix*, *Lithogaster*, &c.) It is, however, in the Jurassic rocks that the *Macrura* attain their maximum development as fossils, all the recent families of the order having now come into existence, and some of them attaining here their culminating point. The Shrimps (*Caridida*) are represented by genera

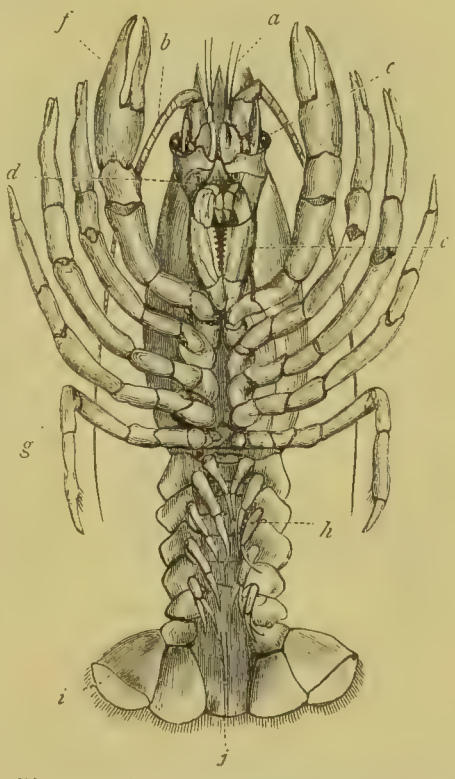


Fig. 424.—The common Cray-fish (*Astacus fluviatilis*), viewed from below. *a*, Antennules; *b*, Antennæ; *c*, Eyes; *d*, Opening of antennary gland; *e*, Last pair of foot-jaws; *f*, One of the great chelæ; *g*, Fifth thoracic limb; *h*, Swimmerets; *i*, The last pair of swimmerets; *j*, The opening of the anus below the telson.

such as *Penæus* and *Æger;* the Spiny Lobsters (*Palinuridæ*) are exemplified by the singular *Mecochirus* (fig. 426) of the Solenhofen Slates, in which the first pair of ambulatory limbs are enormously elongated, but do not terminate in pincers; the *Glyphæidæ* are represented by *Glyphæa* itself, and the genus *Pseudastacus* takes the place of the modern Lobsters. The most remarkable group of the Jurassic *Macrura* is, however, that of the *Eryonidæ*, of which the principal genus is *Eryon* itself. This interesting family has representatives in the Trias, and is very widely distributed in the Jurassic and Cretaceous rocks, while recent investigations have shown that a few forms of the group (such as *Willemoësia*) still maintain their existence at the bottom of the deep sea. In *Eryon* (fig. 427), the carapace is large and broad, and nearly quadrate in figure, whilst the antennæ are very small; the first four pairs of ambulatory legs are chelate, and the first pair are much longer than the others; and the caudal extremity is constituted by the triangular telson and the dilated last pair of swimmerets. Beautifully preserved examples of *Eryon* are found in the Lithographic

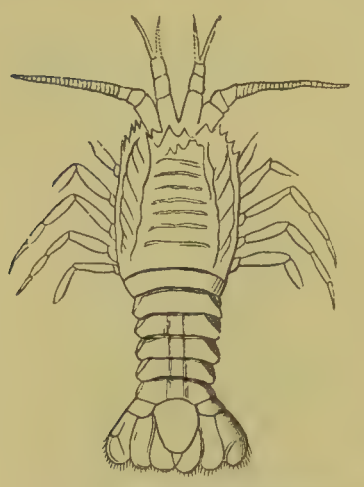


Fig. 425.—*Anthrapalæmon gracilis*, of the natural size. From the Coal-measures of North America. (After Meek and Worthen.)

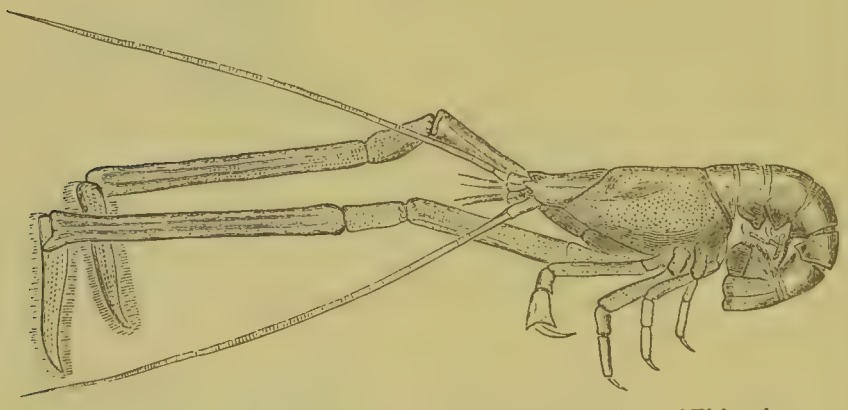


Fig. 426.—*Mecochirus longimanus*, from the Lithographic Slates of Eichstadt, one-half the natural size. (After Zittel.)

Slates of Germany, and in the same deposits are found the remains of "Phyllosomæ," which are to be regarded as the larval stages of the former. In the Cretaceous rocks, Macrurous Decapods are tolerably numerous, and belong to all the principal sections of the

tribe. Among the more characteristic Cretaceous genera may be mentioned *Enoploclytia*, *Hoploparia*, *Meyeria*, *Palinurus*, and *Scyllarus*. Very abundant also in parts of the Cretaceous series are the great chelæ of burrowing Crabs belonging to the genus *Callianassa*, a type which appeared in the Jurassic rocks, and which survives at the present day. In the Tertiary rocks, finally, the remains of *Macrura* are comparatively scanty, and present few points of special interest. The recent genus *Homarus*, including the common Lobster, appears in the Oligocene deposits, and in the fresh-water Tertiary deposits of North America are found the remains of Cray-fishes (*Astacus*) essentially similar to existing forms.

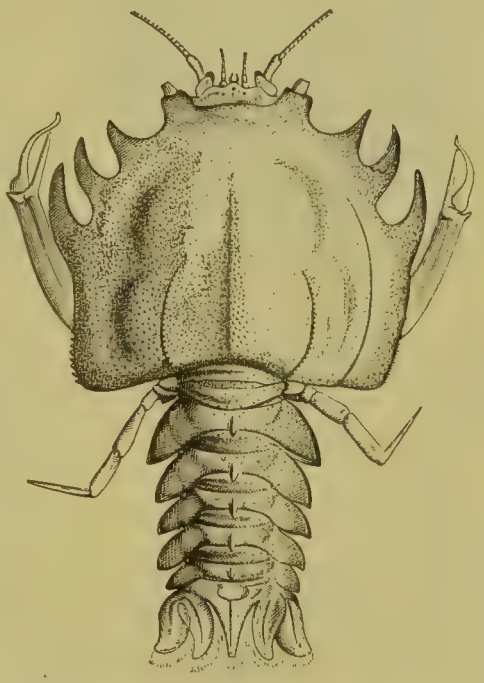


Fig. 427.—*Eryon arctiformis*. Jurassic rocks. (Solenhofen Slates.)

Tribe B. Anomura.—The Decapods which belong to this tribe are distinguished by the condition of the abdomen, which is neither so well developed as in the *Macrura*, nor so rudimentary as in Crabs. The last pair of thoracic limbs are reduced in size. Further, the abdomen does not terminate posteriorly in a caudal fin, as in the *Macrura*.

The division *Anomura* must be regarded as an artificial assemblage, composed of modified forms of both the *Macrura* and *Brachyura*. It is, in fact, impossible to draw a rigid line between the *Anomura* and the *Brachyura*—the two tribes being connected by transitional forms, which might with equal propriety be placed in either. The most characteristic forms of the *Anomura* are the "Hermit-crabs" (*Pagurus*, *Cœnobita*, &c.), and the "Plated Lobsters" (*Galathea*). The Hermit-crabs are interesting on account of their habit of protecting the soft abdomen within the empty shell of some Mollusc (fig. 428). Many of the Hermits, such as the *Cœnobitæ* of the tropics, are terrestrial in their habits, and commonly employ the shells of snails for their borrowed dwelling. As the *Cœnobitæ* migrate to the sea for the purpose of pro-

ducing their eggs, it is conceivable that by their agency a curious and puzzling intermixture of land-shells with marine types of Molluscs might be effected.

With regard to the distribution of the *Anomura* in time, our knowledge is at present very imperfect. If the group of Decapods represented by the living Sponge-crabs (*Dromia*) be referred to the *Brachyura*, then it is doubtful if any remains of the *Anomura* have been found in any Mesozoic deposit, while Palæozoic forms are



Fig. 428.—Hermit-crab (*Cœnobita*) in its borrowed shell. After Morse.

wholly unknown. The claws of a form resembling *Galathea* have been recorded as occurring in the Faxoe Chalk; but with this exception the earliest unquestionable remains of Anomurous Decapods are referable to the genus *Pagurus*, and are found in the Eocene deposits.

Tribe C. Brachyura.—The "short-tailed" Decapods, or Crabs, are distinguished from the two preceding tribes by the rudimentary condition of the abdomen, which is very short, and is tucked up beneath the cephalothorax, the latter being disproportionately large. There is no caudal fin, and there are from one or two (males) to four (females) pairs of abdominal appendages, which are employed by the females in carrying the ova. The Crabs are mostly furnished with ambulatory limbs, and are rarely formed for swimming, most of them being littoral in their habits, and some even living inland.

With regard to their geological history, it is very doubtful if any genuine representatives of the *Brachyura* have been hitherto detected in the Palæozoic series. The *Gitocrangon granulatus* of the Devonian rocks, the *Brachypyge carbonis* of the Carboniferous, and the *Hemitrochiscus paradoxus* of the Permian deposits, which have been supposed to be ancient types of the *Brachyura*, are all more or less problematical in nature. Even in the Jurassic rocks the

evidence of the existence of genuine Crabs is not perfectly clear; since the *Palæinachus longipes* of the Forest Marble (Lower Oolites), described by Dr Henry Woodward as a Crab, is not completely known, and the Jurassic genus *Prosopon* may perhaps be referable to the *Anomura*. In the Cretaceous rocks there are various Decapods of the family of the Sponge-crabs, which form a transitional group between the *Brachyura* and *Anomura*, such as the genus *Dromiopsis;* but there are also genuine Crabs, such as *Palæocorystes*, *Eucorystes*, *Necrocarcinus*, *Etyus*, and *Xantho*, representing several of the existing families of the *Brachyura*. The Eocene deposits, and particularly those of Britain (the London Clay), have proved very rich in the remains of Brachyurous Decapods, some of the forms of this period belonging to extinct genera (such as *Micromaia*, *Psammocarcinus*, *Palæocarpilius*, fig. 429, *Lobocarcinus*, *Xanthilites*, and, above all, *Xanthopsis*), while others are referable to such existing genera as *Cancer* and *Xantho*. The later Tertiary deposits have yielded comparatively few remains of *Brachyura*, and these of little special interest, but the fresh-water genus *Telphusa* and the terrestrial genus *Gecarcinus* are both represented in the Miocene deposits of Œningen.

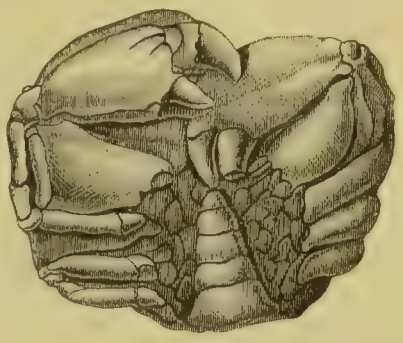


Fig. 429.—*Palæocarpilius macrocheilus.* Eocene.

LITERATURE OF CRUSTACEA.

General.

1. "Gliederfüssler." 'Bronn's Klassen und Ordnungen des Thierreichs,' vol. v. Gerstaecker. 1866-89.
2. Article "Crustacea," in 'Encyclopædia Britannica,' 9th ed. vol. vi. Henry Woodward. 1877.
3. "Histoire Naturelle des Crustacés." Milne-Edwards. 1834-40.
4. "Histoire Naturelle des Crustacés fossiles." Brongniart and Desmarest. 1822.
5. "Catalogue of the British Fossil Crustacea." Henry Woodward. 1877.
6. "Crustacea of the United States Exploring Expedition." Dana. 1852-53.
7. "Handbuch der Palæontologie." Bd. I., Abth. 2. 1885. Zittel.

Cirripedia.

8. "Monograph of the Cirripedia." Darwin. 'Ray Society.' "Lepadidæ," 1851. "Balanidæ," 1854.

9. "Fossil Lepadidæ of Britain." Darwin. 'Palæontographical Society.' 1851.
10. "Fossil Balanidæ of Britain." Darwin. 'Palæontographical Society.' 1854.
11. "Report on the Cirripedia." 'Challenger Reports.' Vols. viii. and x. 1883, 1884. Hoek.
12. "On a New Genus of Cirripedia." Henry Woodward. 'Quart. Journ. Geol. Soc.,' vol. xxi. 1865. (*Turrilepas.*)
13. "Système Silurien de la Bohême." Barrande. Vol. i., Supplement. 1872. (*Plumulites* and *Anatifopsis.*)
14. "Monographie des Crustacés fossiles du terrain crétacé du duché de Limbourg." 1854. Bosquet.
15. "Ueber fossile Lepadiden." 'Sitzungsber. d. k. k. Akad. d. Wissenchaften,' Wien. Bd. 49. 1864. Reuss.
16. "Bemerkungen über einige fossile Lepaditen aus dem Lithographischen Schiefer und der oberen Kreide." 'Sitzungsber. d. bayer. Akad.' 1884. Zittel.
17. "Palæontology of New York." Vol. vii. 1888. (*Protobalanus*, &c.) Hall and Clarke.

Ostracoda.

18. "Natural History of British Entomostraca." Baird. 'Ray Society.' 1850.
19. "Monograph of the Recent British Ostracoda." G. S. Brady. 'Trans. Linn. Soc.' 1866.
20. "Översigt af Norges marine Ostracoder." G. O. Sars. 1865.
21. "Monographie der Ostracoden." 'Wiegmann's Archiv.' Bd. xx. 1854. Zenker.
22. "Monograph of the Entomostraca of the Cretaccous Formation of England." Rupert Jones. 'Palæontographical Society.' 1849.
23. "Monograph of the Tertiary Entomostraca of England." Rupert Jones. 'Palæontographical Society.' 1856.
24. "Palæozoic Bivalved Entomostraca." Rupert Jones. 'Ann. and Mag. Nat. Hist.' 1855-1869.
25. "Carboniferous Entomostraca of Britain." Rupert Jones, J. W. Kirkby, and G. S. Brady. 'Palæontographical Society.' 1874 and 1884.
26. "Post-Tertiary Entomostraca of Scotland." G. S. Brady, H. W. Crosskey, and D. Robertson. 'Palæontographical Society.' 1874.
27. "Monograph of the Ostracoda of the Antwerp Crag." G. S. Brady. 'Trans. Zool. Soc.,' vol. x. 1878.
28. "Système Silurien de la Bohême." Barrande. Vol. i., Supplement. 1872.
29. "Description des Entomostracés fossiles des terrains tertiaires de la France et de la Belgique." 'Mém. de l'Acad. Roy. de Belgique.' Vol. xxiv. 1852. Bosquet.

Phyllopoda and Phyllocarida.

30. "Zur Kenntniss des Baues und der Entwickelung von Branchipus stagnalis und Apus cancriformis." 'Abh. d. k. Ges. d. Wissenschaften.' Göttingen. 1873. Claus.

31. "A Monograph of the Phyllopod Crustacea of North America." 'Twelfth Ann. Report of the U.S. Geol. and Geog. Survey of the Territories.' 1883. Packard.
32. "Report on the Phyllocarida." 'Challenger Reports,' vol. xix. 1887. G. O. Sars.
33. "Fossil Estheriæ." Rupert Jones. 'Palæontographical Society.' 1862.
34. "Peltocaris, a New Genus of Crustacea." Salter. 'Quart. Journ. Geol. Soc.,' vol. xix. p. 87. 1863.
35. "Hymenocaris." Salter. 'Mem. Geol. Survey,' vol. iii., Appendix. 1866.
36. "Crustacean Teeth of the Carboniferous and Silurian." Henry Woodward. 'Geol. Mag.,' vol. ii. 1865.
37. "Discinocaris." Henry Woodward. 'Quart. Journ. Geol. Soc.,' vol. xxii. 1866.
38. "Aspidocaris." Reuss. 'Sitzungsber. d. Akad. Wien.' 1867.
39. "Système Silurien de la Bohême." Barrande. Vol. i., Supplement. 1872.
40. "Dithyrocaris." Henry Woodward and R. Etheridge, jun. 'Geol. Mag.,' vol. x. 1873.
41. "A Monograph of the British Palæozoic Phyllopoda (Phyllocarida, Packard)." Part i. Ceratiocaridæ. 'Palæontographical Society.' 1888. Rupert Jones and Henry Woodward.
42. "Ceratiocaridæ from the Chemung and Waverley Groups." 'Rep. of Progress: 2d Geol. Survey of Pennsylvania.' 1884. Beecher.
43. "Remarques sur le genre Aristozoë, Barrande." 'Sitzungsber. d. k. Böhm. Ges. d. Wissenschaften.' 1885. Novák.

Trilobita.

44. "Système Silurien de la Bohême." Vol. i., 1852, and Supplement, 1872. Barrande.
45. "Crustacea formationis transitionis." 1878. Angelin.
46. "Monograph of the British Trilobites." 'Palæontographical Society.' 1864-67. Salter.
47. "Ueber einige Böhmische Trilobiten." 1845. Also, "Untersuchungen über Trilobiten." 1846. Beyrich.
48. "Organisation of Trilobites." Burmeister. 'Ray Society.' 1846.
49. "British Organic Remains." Salter. 'Mem. Geol. Survey,' decade ii. 1849. Also 'Mem. Geol. Survey,' vol. iii. 1866.
50. "Catalogue of British Fossil Crustacea." Henry Woodward. 1877.
51. "Palæozoic Fossils of Canada." Vol. i. 1861-65. Billings.
52. "Prodrom einer Monographie der böhmischen Trilobiten." 1874. Hawle and Corda.
53. "Palæontology of New York." Vols. i. and ii., 1847-52, Hall; and vol. vii., 1888, Hall and Clarke.
54. "Revision der ostbaltischen Silurischen Trilobiten." 'Mém. de l'Acad. imp. de St Pétersbourg.' 1881, 1883, 1885. Friedrich Schmidt.
55. "The Trilobite." 'Bull. Mus. Comp. Zool.' Vol. viii. 1881. Walcott.
56. "Monograph of the British Carboniferous Trilobites." 'Palæontographical Society.' 1883-84. Henry Woodward.

Xiphosura and Eurypterida.

57. "Recherches sur l'anatomie des Limules." 'Annales des Sci. Nat.' A. Milne-Edwards. 1873.
58. "On the Anatomy and Development of the American King-Crab." Owen. 'Trans. Linn. Soc.' 1872.
59. "Development of Limulus polyphemus." A. S. Packard. 'Mem. Boston Soc. Nat. Hist.' 1871.
60. "The Anatomy, Histology, and Embryology of Limulus polyphemus." 'Anniversary Mem. of the Boston Soc. of Nat. Hist.' 1880. Packard.
61. "Zur Embryologie und Morphologie des Limulus polyphemus." Dohrn. 'Jenaische Zeitschr.' 1871.
62. "Recherches sur l'hist. nat. et Anat. des Limules." Van der Hoeven. 1838.
63. "Limulus an Arachnid." 'Quart. Journ. Mic. Sci.' Ray Lankester. 1881.
64. "On the relation of the Xiphosura to the Eurypterida." Henry Woodward. 'Quart. Journ. Geol. Soc.' 1872.
65. "Die Crustaceen-fauna der Eurypterus-Schichten von Rootziküll auf Oesel." 'Mém. de l'Acad. imp. de St. Pétersbourg.' Friedrich Schmidt. 1883.
66. "Monograph of the Genus Pterygotus." Huxley and Salter. 'Mem. Geol. Survey,' monograph i. (with atlas). 1859.
67. "Monograph of the British Fossil Crustacea belonging to the Order *Merostomata*." Henry Woodward. 'Palæontographical Society.' 1866-78.
68. "British Palæozoic Crustacea belonging to the Order *Merostomata*." Henry Woodward. 'Geol. Magazine,' vol. ix. 1872. (*Hemiaspis*.)
69. "On a New King-Crab from the Upper Silurian." Henry Woodward. *Ibid*., vol. v. 1868. (*Neolimulus*.)
70. "Contributions to British Fossil Crustacea." Henry Woodward. 'Geol. Magazine,' vol. vii. 1870. (*Cyclus*.)
71. "Exapinurus and Pseudoniscus." Nieszkowski. 'Archiv für Naturkunde Liv. Ehst. und Kurlands,' ser. i. vol. ii. 1859.
72. "Eurypterus." James Hall. 'Pal. N. York,' vol. iii. 1859.

Malacostraca.

73. "A History of the British Sessile-eyed Crustacea." 1863-68. Spence Bate and J. O. Westwood.
74. "Catalogue of the specimens of Amphipodous Crustaceans in the Collection of the British Museum." Spence Bate. 1862.
75. "Untersuchungen über die Bildung und Entwickelung der Wasserasseln." Rathke. 1832.
76. "Crustacea Amphipoda borealia et arctica." Boëck. 1871.
77. "On a Fossil Crustacean found in the Magnesian Limestone of Durham," &c. Spence Bate. 'Quart. Journ. Geol. Soc.,' vol. xv. 1859. (*Prosoponiscus*.)
78. "Ein Beitrag zur Kenntniss der fossilen Asseln." 'Sitzungsber. d. bayer. Akad.' 1882. Von Ammon.
79. "On Eocene Crustacea from Gurnet Bay, Isle of Wight." 'Quart. Journ. Geol. Soc.' 1879. Henry Woodward.

80. "Contributions to British Fossil Crustacea." Henry Woodward. 'Geol. Magazine,' vol. vii. 1870. (*Palæga.*)
81. "Report on the Cumacea." 'Challenger Reports,' vol. xix. 1887. G. O. Sars.
82. "Monographie over de ved Norges Kyster forekommender Mysider." G. O. Sars. 1870-79.
83. "Report on the Schizopoda." 'Rep. on the Sci. Results of the Challenger Exped.,' vol. xiii. 1885. G. O. Sars.
84. "Palæontology of Illinois." Vols. ii. and iii. 1866 and 1868. Meek and Worthen. (*Palæocaris*, *Gampsonyx*, *Acanthotelson*, and *Anthrapalæmon.*)
85. "Archæoniscus Brodiei." Westwood, in Brodie's 'Insects of the Secondary Rocks.' 1845.
86. "Report on the Stomatopoda." 'Challenger Reports,' vol. xvi. 1886. Brooks.
87. "On a Fossil Squilla from the London Clay of Highgate." 'Quart. Journ. Geol. Soc.' 1879. Henry Woodward.
88. "Versuch einer Naturgeschichte der Krabben und Krebse." Herbst. 1782-1804.
89. "Monograph of the Malacostracous Crustacea of Great Britain." Bell. 'Palæontographical Society.' 1857 and 1862.
90. "Fossilen Krebse von Bayern." Münster. 'Beiträge zur Petrefaktenkunde,' vol. ii. 1839.
91. "Neue Gattungen fossiler Krebse." Von Meyer. 1840.
92. "Palæozoic Macrura." Salter. 'Quart. Journ. Geol. Soc.,' vols. xvii. and xix. 1861 and 1863. (*Anthrapalæmon.*)
93. "Palæozoic Macrura." Huxley. 'Quart. Journ. Geol. Soc.,' vols. xiii. and xviii. 1857 and 1862. (*Pygocephalus.*)
94. "Notice of New Forms of Fossil Crustaceans from the Upper Devonian Rocks of Ohio." (*Palæopalæmon.*) 'Amer. Journ. Sci. and Arts.' 1880. Whitfield.
95. "Jurassische und Triassische Crustaceen." 'Palæontographica.' 1854. Von Meyer.
96. "On New Crustacea from the Lower Carboniferous Rocks of Eskdale and Liddesdale." 'Trans. Roy. Soc., Edin.' 1880 and 1882. Benjamin N. Peach.
97. "Die Macruren-Decapoden der Senon- und Cenoman-Bildungen Westfalens." 'Zeitschr. d. deutsch. Geol. Ges.' 1862. Schlüter.

CHAPTER XXXI.

ARTHROPODA—continued.

ARACHNIDA AND MYRIOPODA.

Class II. Arachnida.

The *Arachnida*—including the Spiders, Scorpions, Mites, &c.—possess almost all the essential characters of the *Crustacea*, to which they are very closely allied. Thus, the body is divided into a variable number of somites, some of which are always provided with articulated appendages. A pair of ganglia is primitively developed in each somite, and the neural system is placed ventrally. The heart, when present, is always situated on the opposite side of the alimentary canal to the chain of ganglia. The respiratory organs, however, whenever these are differentiated, are never in the form of branchiæ as in the *Crustacea*, but are in the form either of pulmonary vesicles or sacs, or of ramified tubes, formed by an involution of the integument, and fitted for breathing air directly. Further, there are never more than four pairs of ambulatory limbs, and no locomotive appendages are developed upon any of the abdominal segments. Antennæ are not present (as such), and the eyes are simple and sessile. The head and thorax are united to form a cephalothorax (the thoracic segments in rare cases remaining free), and in some cases the cephalothorax is fused with the abdomen.

Speaking generally, therefore, the *Arachnida* are distinguished from the *Crustacea* by *the possession of four pairs of walking-legs, the want of locomotive appendages on the abdomen, and the absence of antennæ; while the breathing-organs* (*when differentiated*) *are adapted for breathing air directly, and are never in the form of branchiæ.*

The integument of the *Arachnida* is in general more or less extensively hardened by chitine, and commonly forms a resistant exoskeleton. Viewed under the microscope, the chitinous exoskeleton of such an Arachnidan as a Scorpion (fig. 430, A and B) exhibits a

finely punctate or minutely porous structure, along with numerous oval pits of different sizes, each of which exhibits a central dark spot or ring. These latter are not perforations, but are the sockets of hairs. The skin of a fossil Scorpion from the Carboniferous rocks (collected by the Geological Survey of Scotland) also exhibits a minutely reticulate or porous structure, and presents larger oval pits, which show a central dark spot, and which seem to be quite similar to the hair-sockets of the recent Scorpions (fig. 430, C and D). There are also still larger oval perforations, which are surrounded by a fibrous ring, and which are true *perforations*, passing completely through the thin integument. These may represent the sockets of large bristles, from which the delicate chitinous membrane forming the original floor of the socket (traces of which are still sometimes visible) has disappeared; or they may be truly pores. In the latter case, they do not appear to have any representative in the integument of the recent Scorpions.

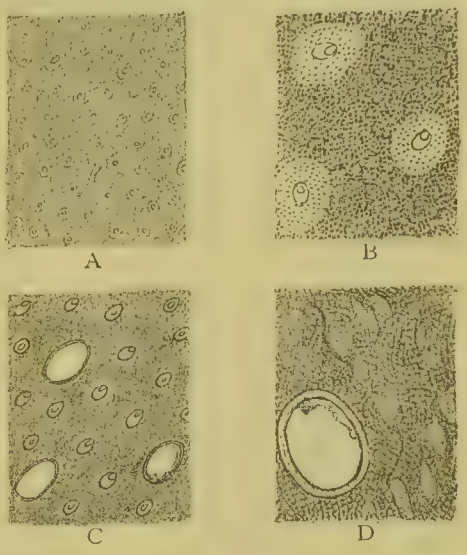


Fig. 430.—A, Exoskeleton of a recent Scorpion enlarged, and (B) still more highly magnified, showing minute pores together with larger pits to which hairs were attached. C, Portion of the skin of a fossil Scorpion from the Carboniferous rocks of Scotland, enlarged, showing pits for the attachment of hairs. The large oval perforations probably also represent the sockets of hairs, of larger size. D, Portion of the same enlarged further, showing a finely reticulate or porous structure. (Original.)

The segments of the head and thorax in the *Arachnida* are generally amalgamated to form a "cephalothorax," which is in some cases (*Solpugidæ*) segmented. The upper surface of the head carries the eyes, which are always simple and are never supported upon movable peduncles. There are no proper "antennæ," but the place of these is taken by a pair of prehensile organs known as the "cheliceræ," "falces," or "mandibles" in different groups of the class (fig. 431, *c*). There is a single pair of "maxillæ" or proper jaws, which carry long jointed appendages—the "maxillary palpi." The palpi are sometimes leg-like in form ("pedipalpi"), or they may, as in the Scorpions, be converted into nipping-claws (fig. 431, *m*). Immediately posterior to the mouth is a lower lip or "labium," which is unpaired in the Spiders, but in some cases is partially divided by a longitudinal groove, and is thus seen to represent a second pair of maxillæ. The four segments of the thorax

carry, as a rule, four pairs of jointed ambulatory legs. Abdominal limbs are present in the embryo of various *Arachnida*, but ambulatory appendages are never developed on the abdominal somites of the adult. In the Scorpions, the first abdominal segment carries a minute "operculum," formed by the coalescence of a pair of appendages, which covers the opening of the reproductive organs; and the second abdominal segment carries the peculiar organs which

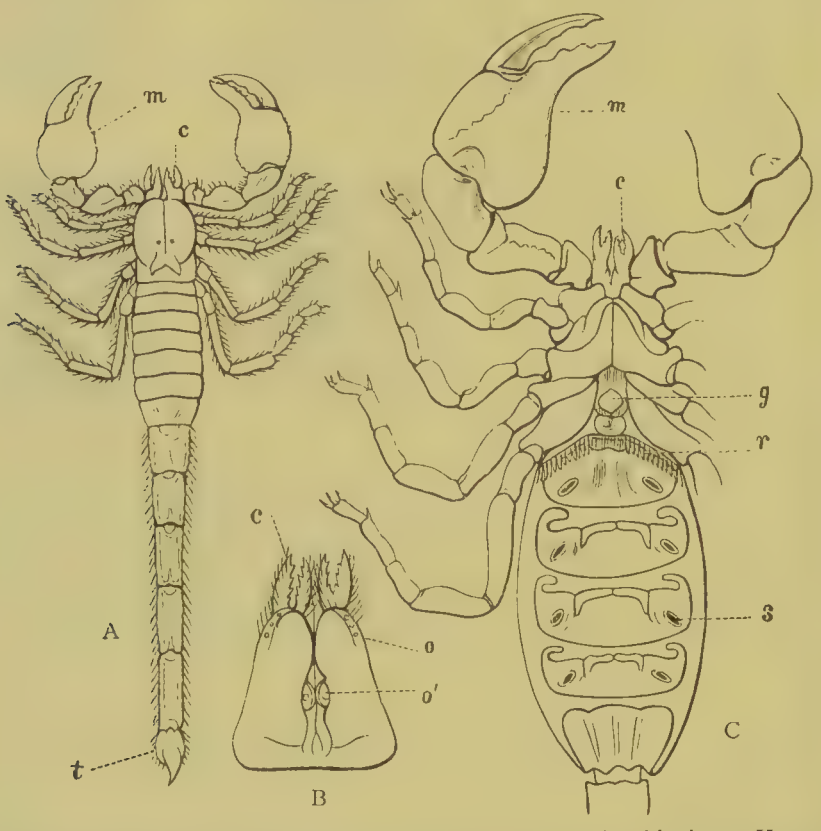


Fig. 431.—A, *Scorpio afer*, viewed from above, and somewhat reduced in size; B, Upper surface of the cephalothorax of the same, enlarged; C, *Buthus Kochii*, with the terminal segments and the ends of the appendages on one side omitted. *m*, Maxillary palpi (behind these are the four pairs of ambulatory legs); *c*, Chelicerae; *t*, Telson; *o*, Lateral ocelli; *o'*, Central, larger ocelli; *g*, Opercular plate, covering the opening of the reproductive organs; *r*, One of the "combs"; *s*, One of the stigmatic openings. (C is after Prof. Ray Lankester.)

are known as the "combs." The extremity of the abdomen carries in the Spiders the so-called "spinnerets" (two, four, or six in number), which have sometimes been regarded as modified abdominal appendages. A "telson" is present in the Scorpions, in which it forms a poisonous "sting"; and a jointed caudal filament is present in *Thelyphonus*.

The higher *Arachnida* are air-breathers, and possess distinct respiratory organs in the form of "tracheæ" or "pulmonary sacs," the

former being tubular and the latter pouch-like in form. The air is admitted to the breathing-organs by paired apertures ("stigmata"), which are mostly placed on the ventral aspect of the abdomen. Many of the lower *Arachnida* have no differentiated respiratory organs; and the Pycnogonids, if rightly placed in this class, are water-breathers.

As regards their *distribution in space*, the higher *Arachnida* are essentially terrestrial in habit. Many of the lower forms are internal or external parasites. A few of the Mites live in the sea or between tide-marks, and the singular Pantopods (*Pycnogonida*) are wholly marine in habit: but the zoological position of these last is uncertain.

As regards their *distribution in time*, our knowledge of the history of the *Arachnida* is still very incomplete. Many of the lower forms are incapable of preservation, while the terrestrial habits of most of the higher forms sufficiently account for their comparative rarity as fossils. The oldest known representatives of the class are the Scorpions, which appear, under forms not very widely different from those now in existence, in the Silurian rocks. The earliest types of the true Spiders (*Protolycosa* and *Phalaranea*) appear in the Coal-measures, where also appear forms allied to the recent *Thelyphonus*. The great majority of the Palæozoic Arachnids, however, differ in various points from existing forms, and have been placed by Scudder in a special order (*Anthracomarti*), which is confined to the Palæozoic period. In the Mesozoic rocks no undoubted remains of Arachnids have hitherto been detected. On the other hand, in the Tertiary rocks are found representatives of all the living orders of Arachnids, except the problematical group of the *Pycnogonida*, which is not known at all in the fossil state. Most of the Tertiary Arachnids have been found in amber—the fossil resin of certain Conifers—and the state of preservation of these is often marvellously perfect. The more important facts relating to the fossil *Arachnida* may be briefly noticed under the following heads:—

1. Acarida.—This group of the *Arachnida* comprises the Mites and Ticks, in which the cephalothorax and abdomen are fused into a single mass, while the mouth-organs are generally adapted for piercing and suction. Breathing organs may be wanting, but when present, are in form of tracheæ. All the principal existing families of Mites are known to be represented in amber (Tertiary). Galls formed by Mites have also been detected on the leaves of fossil Willows in the Tertiary beds of Europe.

2. Anthracomarti.—This order has been founded for the reception of certain Palæozoic Arachnids, in which the body is somewhat compressed, the cephalothorax and abdomen are distinctly

separated from one another, and the former is usually composed of more or fewer wedge-shaped, foot-bearing segments. The abdomen consists of from four to nine somites, and the "palpi" are not much longer than the legs, and are not terminated by pincers or claws (Scudder). Of the genera included in this extinct group, all of which are confined to the Carboniferous period, *Architarbus* (fig. 432, B) is found in the Coal-measures of both Europe and North America. In *A. subovalis* the cephalothorax is shorter than the abdomen and carries four pairs of legs and a pair of palpi, the form of which is unknown. The abdomen consists of nine seg-

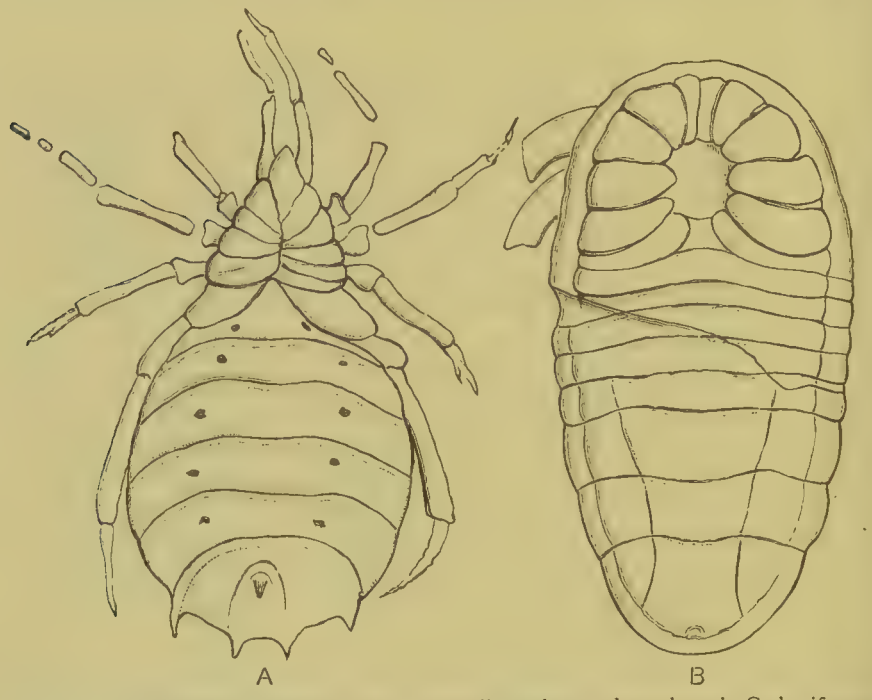


Fig. 432.—A, *Eophrynus Prestvicii*, viewed ventrally, and somewhat enlarged—Carboniferous; B, *Architarbus subovalis*, enlarged four times, and viewed from below—Carboniferous (after H. Woodward).

ments, of which the anterior ones are much narrower than the hinder ones. In *Anthracomartus*, also distributed in the Coal-measures of Europe and North America, the cephalothorax is quadrangular, and is only about half as wide as the abdomen, the latter region consisting of seven segments. In *Arthrolycosa*, from the Coal-measures of Illinois, the cephalothorax, on the other hand, is round, and is much larger than the abdomen, the latter region consisting of seven distinct segments and being comparatively narrow. Lastly, in the singular genus *Eophrynus* (fig. 432, A), the cephalothorax is triangular and extended in front, and carries the four pairs of legs and a pair of slender palpi. The abdomen is twice as large

as the cephalothorax, and its upper surface is tuberculated, while on its ventral aspect are seen the openings of six pairs of stigmata.

3. Adelarthrosomata.—Under this name may be included Arachnidans such as the "Book-scorpions" (*Pseudoscorpionidæ*) and the "Harvest-men" (*Phalangidæ*), in which the abdomen is more or less distinctly segmented, but is not clearly separated from the cephalothorax, the two regions being of equal width and conjoined together; while the respiratory organs have the form of tracheæ. Various Tertiary forms of the Pseudoscorpions have been detected—principally in amber—but these all belong to existing genera (*Chelifer*, *Chernes*, &c.) Of the *Phalangidæ* no other fossil forms are known except those which occur in amber, and of these a number of types, belonging to several genera, have been described.

4. Pedipalpi.—Under this head may be included the two groups of the Scorpions (*Scorpiodea*) and the *Phrynidea*, in which the abdomen is segmented, with or without a "post-abdomen," and the breathing-organs are in the form of pulmonary sacs. The Scorpions are characterised by their compressed bodies, and by the clear separation of the cephalothorax from the long and segmented abdomen. The abdomen proper consists of seven wide somites, of which the first carries on its ventral surface the opening of the generative organs, closed by a delicate lid or operculum (fig. 431, *g*); the second carries a pair of peculiar comb-like appendages ("pectines"), the precise function of which is not known; and the next four exhibit the oblique apertures ("stigmata") of the four pairs of pulmonary sacs. The abdomen proper is followed by six narrower segments, which constitute a "post-abdomen," and of which the last (the "telson") is hooked, and is converted into a poisonous "sting." The cephalothorax is covered by a shield-like carapace, the upper surface of which carries a variable number of simple eyes, one pair of which is larger than the others, and is placed dorsally, while the smaller eyes are marginal. The first pair of cephalic appendages, corresponding with the "falces" of the Spiders, are converted into nipping-claws ("cheliceræ"); the maxillary palpi are very large and end in pincers; and a partially divided lower lip is present. The four thoracic segments carry the four pairs of walking-legs.

The Scorpions possess a resistant chitinous exoskeleton, readily capable of preservation in the fossil condition (see p. 573). It is also probable that some of the more ancient forms were littoral in habit, which would account for the occurrence of their remains in strata of marine origin. The Scorpions are the most ancient group of the *Arachnida*, being represented in the Silurian rocks of both the Old and New Worlds. Various Carboniferous Scorpions are

also known, and these ancient types do not appear to have differed from the living representatives of the group except in comparatively non-essential characters.

The genus *Palæophonus* (fig. 433) has been detected in the Silurian strata of Gotland and of Scotland, and comprises Scorpions which differ from all existing types in the fact that the walking-legs gradually taper to their ends, which terminate in points or simple claws. The maxillary palpi form strong nipping-claws, and the median eye-tubercles are placed not far from the anterior margin of the cephalothorax. The genus *Proscorpius* occurs in the Silurian deposits of North America, and differs from the preceding in the



Fig. 433.—Ventral aspect of a species of *Palæophonus*, from the Silurian rocks of Lesmahagow, Lanarkshire. Enlarged nearly twice. (After Benjamin N. Peach.)



Fig. 434.—A specimen of *Eoscorpius carbonarius*, from the Carboniferous rocks of Illinois, of the natural size. (After Meek and Worthen.)

fact that the legs are long, with blunt terminal joints ending in two claws. The median dorsal eye-tubercles are placed on the anterior margin of the cephalothorax, and the lateral eyes are on ridges, as in the living Scorpions. The genus *Eoscorpius* (fig. 434) is confined to the Carboniferous rocks, and species have been detected in the Coal-measures of both Europe and North America. *Mazonia* is probably identical with *Eoscorpius*. The genus is nearly related to *Proscorpius*, from which it differs in having the median dorsal eye-tubercles of smaller size, and not placed close to the anterior margin of the cephalothorax. The Coal-measures of Europe and North America have also yielded the remains of Scorpions on which the genus *Cyclophthalmus*—including the first fossil forms known to

science—was founded. In this genus (fig. 435) the median dorsal eye-tubercles are of very large size, and occupy almost half of the cephalothorax towards the anterior margin, while the lateral eyes form a semicircle behind and to the sides of the great dorsal eyes, and the palpi are developed into nipping-claws of very large size. According to Mr Scudder, the four genera just mentioned constitute a special division of the Scorpions (*Anthracoscorpii*), characterised, among other points, by the fact that the dorsal eye-tubercles are either placed on the anterior margin of the cephalothorax or a short distance behind it. On the other hand, in the Scorpions of the



Fig. 435.—*Cyclophthalmus senior.* A fossil Scorpion from the Coal-measures of Bohemia.

more modern type (*Neoscorpii*), the median eye-tubercles are, as a rule, far removed from the anterior margin of the cephalothorax, and are placed behind the lateral eyes. It is a singular fact that while the *Anthracoscorpii* are wholly confined to the Palæozoic rocks, no example of the *Neoscorpii* has hitherto been detected in the Mesozoic or in the earlier Kainozoic deposits. The only known fossil representative of the *Neoscorpii*, in fact, is a late Tertiary form (*Tityus eogenus*) which has been discovered in amber.

The remaining section of the *Pedipalpi* is that of the *Phrynidea*, which differs from the Scorpions in the fact that the cephalothorax is sharply separated from the abdomen, and is occasionally divided into two distinct regions. The maxillary palpi are greatly developed,

but terminate in claws or in imperfect pincers, and the abdomen does not terminate in a "sting." The existing genus *Phrynus* has been detected in Tertiary deposits, while the recent genus *Thelyphonus* is represented in the Carboniferous rocks by the genus *Geralinura*.

5. Araneida.—This division of the *Arachnida* includes the true Spiders, characterised by the soft and imperfectly segmented abdomen, which carries two, four, or six "spinnerets" posteriorly, and is united in front with the cephalothorax by a constricted peduncle. The maxillary palpi are slender and leg-like, and never terminate in nipping-claws, while the "falces" or "mandibles" are hooked, and contain a poison-gland in their base. The most ancient representatives of the Spiders, so far as at present known, are the *Protolycosa anthracophila*, and *Phalaranea borassifolia* of the Coal-measures of Europe, both of which have been referred to the section of the *Territelariæ*. No Mesozoic Spiders have hitherto been discovered; but about seventy genera have been recognised as occurring in Tertiary deposits—many of them in amber. About one-half of the known Tertiary genera of Spiders are without representatives at the present day.

Class III. Myriopoda.

The class of the *Myriopoda* includes the multisegmentate, worm-like Arthropods known as the Centipedes and Millepedes, and is characterised by the fact that *the head is distinct, and the remainder of the body is divided into nearly similar segments, the thorax exhibiting no clear line of demarcation from the abdomen. There is one pair of antennæ, and the number of the legs is always more than eight pairs. Respiration is by tracheæ.*

In this class of the *Arthropoda* the head is always distinctly marked off from the rest of the body, and consists of five or six amalgamated somites. The head carries a single pair of jointed antennæ, which are usually simple (fig. 436), but are bifid, and carry many-jointed appendages in the aberrant genus *Pauropus*. Behind the antennæ there is generally a variable number of simple sessile eyes. The mouth is placed on the under side of the head, and is provided with mandibles and maxillæ. The Centipedes also possess two pairs of "foot-jaws," of which the hindmost pair (fig. 436, *f*) are of large size, and are terminated by perforated hooks, which communicate with internally-placed poison-glands. These appendages, however, are not carried upon the head, but are attached to a special segment formed by the amalgamation of the anterior thoracic rings. The segments behind the head are numerous, and there is no distinct line of demarcation between those

which belong to the thorax and those which are referable to the abdomen. The post-cephalic segments, with the exception of the last, usually carry a single pair of jointed legs each. Among the living Myriopods, *Pauropus* has only nine pairs of legs; but, with this exception, eleven pairs of legs is the smallest number possessed by any existing type. In the Millepedes (*Diplopoda*) each apparent segment carries two pairs of legs (fig. 437); but this is really due to

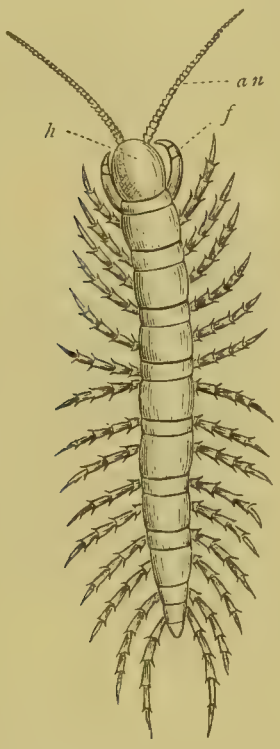


Fig. 436.—*Lithobius forficatus*, a recent Centipede, enlarged, and viewed dorsally. *an*, Antennæ; *h*, Head; *f*, Foot-jaw.



Fig. 437.—*Iulus maximus*, a recent Millepede.

the coalescence of the somites in pairs, each apparent segment being in reality composed of two amalgamated somites.

In the abnormal genus *Pauropus* respiration is cutaneous, but in all other living Myriopods the breathing-organs are in the form of "tracheæ"—that is to say, tubes which open on the surface of the body by minute apertures or "stigmata," and which convey the air into the interior of the body. In *Peripatus* the tracheæ open externally by irregularly placed "stigmata" over the whole surface of the body. In the Centipedes the "stigmata" are placed on the sides of the body on alternate segments. In the Millepedes (*Diplo-*

poda), on the other hand, in which the segments are amalgamated in pairs, the stigmata are placed on every apparent ring.

The recent Myriopods are grouped into the four orders of the *Chilopoda* (Centipedes), *Diplopoda* (Millepedes), *Pauropoda* (*Pauropus*), and *Onychophora* (*Peripatus*). To these Scudder has added the two extinct orders of the *Protosyngnatha* and *Archipolypoda* for the reception of the Palæozoic types of Myriopods.

As regards their distribution in time, all the recent Myriopods are terrestrial in habit. As a necessary result of this, the remains of Myriopods are not abundant as fossils, and have been mostly found in deposits of distinctly fresh-water or estuarine origin. The occurrence of Myriopods in unequivocally marine strata is, however, by no means unknown, though difficult with our present knowledge to satisfactorily explain. The two living orders of the *Pauropoda* and *Onychophora*—represented each by a single genus only—are unknown as fossils, and require no further consideration here. The other two existing orders—viz., the *Chilopoda* and *Diplopoda*—are represented only by Tertiary types, with the possible exception of a Cretaceous form of the latter order. On the other hand, a considerable number of Palæozoic Myriopods are known, which differ more or less widely from all existing types, and for the reception of which Mr Scudder has founded the two orders of the *Protosyngnatha* and *Archipolypoda*. The only known representative of the *Protosyngnatha* is the genus *Palæocampa*, which is found in the Coal-measures of North America. The oldest Myriopods, however, belong to the *Archipolypoda*, and remains of early forms of this order have been described by Mr Peach as occurring in the Old Red Sandstone of Scotland. It is, however, in the Carboniferous rocks that this ancient group of Myriopods attains its maximum development, about thirty different species having been already described from the Coal-measures of the Old and New Worlds. There are also a few Myriopods known to occur in the Permian rocks of Europe, which probably belong to the same order. In the following a brief account is given of the four orders of Myriopods which are known to be represented by fossil forms.

Order I. Protosyngnatha.—This order comprises only the single genus *Palæocampa*, of which only a single species (*P. anthrax*) has been hitherto recorded. In this remarkable genus (fig. 438) the body is comparatively short and worm-like, consisting of few segments, each body-ring being furnished with a single dorsal and ventral plate. Each segment carries a pair of stout fleshy legs, and the upper surface is furnished with large tubercles, each of which supports a cluster of long needles, and which are arranged in longitudinal rows. The sole known species of *Palæocampa* is found in the Coal-measures of Illinois; and the possession of the bundles

of long bristles above mentioned gives to the fossil the aspect of the caterpillar of such a Moth as the Tiger-moth.

Order II. Chilopoda.—This order includes the recent Centipedes (fig. 436), characterised by their elongated depressed bodies, each body-ring being protected by a dorsal plate above, and a corresponding ventral plate below. The first two pairs of thoracic appendages are converted into foot-jaws, the second pair being of large size and hooked, and being connected with poison-glands. All the remaining body-rings carry a single pair of jointed legs each, and the tracheal stigmata are usually placed on alternate segments. The generative organs open at the posterior end of the body.

With the exception of the problematical *Geophilus proavus* of the Lithographic Slates (Jurassic) of Germany, the oldest known

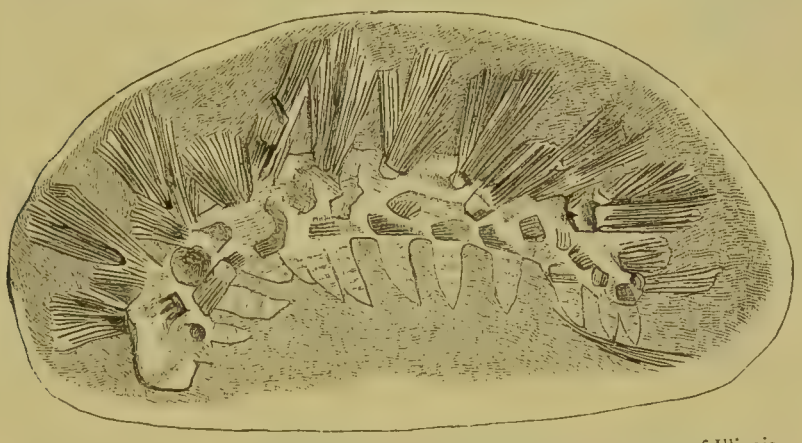


Fig. 438.—A specimen of *Palæocampa anthrax*, from the Coal-measures of Illinois, enlarged twice. (After Scudder.)

remains of Centipedes are of Tertiary age. Most of these have been found in amber, and they all fall under existing families of the order.

Order III. Archipolypoda.—This order has been founded by Scudder for the reception of a number of Palæozoic Myriopods, and is characterised as follows: The body in the *Archipolypoda* is fusiform and elongated, composed of many segments, and thickest in the anterior half or third. The cephalic appendages are borne upon a single apparent segment. The body-segments are provided each with a pair of ventral plates and a more or less divided dorsal plate, "the latter occupying the upper surface and most of the sides of the body, and divided more or less conspicuously into a ridged anterior and a lower posterior portion, the anterior frequently bearing spines or tubercles." The ventral plates are as broad as the body, each bearing a pair of long corneous legs, approximated at the base, and

furnished outside the legs with large stigmata directed transversely to the axis of the body (Scudder). This order comprises all the Palæozoic *Myriopoda* with the exception of the Carboniferous genus *Palæocampa*, and it is not known to have any representatives in the Mesozoic or Kainozoic rocks. The most ancient types of the *Archipolypoda* at present known are those recorded by Page and Peach as occurring in the Old Red Sandstone of Scotland (*Kampecaris* and *Archidesmus*). With these exceptions, all the members of the order are either Carboniferous or Permian in age. The three most important genera of the *Archipolypoda* are *Euphoberia*, *Archiulus*, and *Xylobius*. In the genus *Euphoberia* (fig. 439) the dorsal shields are divided each into two more or less closely consolidated, but distinctly separate sub-segments, one of which is much more elevated than the other. The segments are generally from two to three times broader than long, and they carry subdorsal and lateral rows of large spines, which are forked and terminate in simple ends. The species of *Euphoberia* are found in the Coal-measures of North

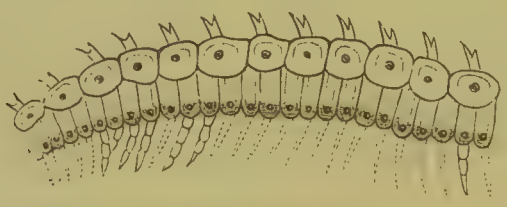


Fig. 439.—Portion of the body of *Euphoberia armigera*, from the Coal-measures of Illinois, of the natural size (after Meek and Worthen). The dark spots on the dorsal shields are pits left by the breaking off of the dorsal spines.

America and Britain. The genus *Acantherpestes* includes Carboniferous Myriopods which differ from *Euphoberia* chiefly in having the spines bifurcated at the tip, though there are other characters of difference as well. *Acantherpestes major*, of the Coal-measures of Illinois, attained a length of about a foot, and "was armed with coarse branching spines more than a centimetre long" (Scudder). Mr Scudder regards this species as having been amphibious in habit, as he considers that certain lateral openings which it exhibits were branchial in character.

The genera *Archiulus* and *Xylobius* constitute a special family (*Archiulidæ*) of the *Archipolypoda*, characterised by the fact that the dorsal plates are "closely consolidated, but still distinctly separable," though the anterior is rarely much elevated above the posterior sub-segment. The body is "almost smooth or covered more or less abundantly with serially disposed papillæ, from which in some cases hairs or small spines arise" (Scudder). These genera are closely allied in some respects to the Millepedes (*Diplopoda*), though they would seem on the whole to be properly referable to a

separate order. In *Archiulus* the dorsal plates are entire, generally from two to three times broader than long, and furnished with a few bristle-bearing papillæ. The best known species of this genus have been found in the Coal-measures; but some imperfectly described Myriopods from the Permian rocks of Bohemia may also belong here. The genus *Xylobius* resembles *Archiulus* in general features, but the segments are divided by longitudinal sutures into numerous quadrate sections. All the known species of this genus are from the Coal-measures.

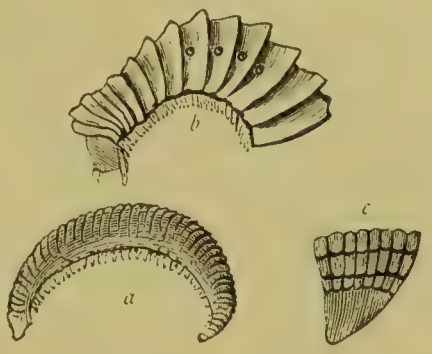


Fig. 440.—*Xylobius Sigillariæ*, a Carboniferous Myriopod (after Dawson). *a*, Natural size; *b*, Anterior portion, enlarged; *c*, Posterior portion, enlarged.

Order IV. Diplopoda (Chilognatha).—This order includes the recent Millepedes, and is characterised by the fact that the body is usually cylindrical, and the body-rings (except the most anterior ones) are fused in pairs, each apparent segment thus coming to carry two pairs of legs. The legs are small and spring from the under surface of the segments, and each apparent ring carries a pair of stigmata. There are no "foot-jaws," and the generative apertures are placed anteriorly, at the base of the second or third pair of legs.

The oldest known fossil representative of the *Diplopoda* is a form (*Iulopsis cretacea*) which has been described from the Cretaceous rocks of Greenland. All the other hitherto recorded fossil Millepedes are of Tertiary age, the majority of the known types having been found in amber.

LITERATURE.

Arachnida and Myriopoda.

1. "Die Arachniden." Hahn and Koch. 1831-49.
2. "Die Insecten und Spinnen der Vorwelt." Giebel. 1856.
3. "On Fossil Arachnidæ, including Spiders and Scorpions." Brodie. 1882.
4. "Die im Bernstein befindlichen Crustaceen, Myriapoden, Arachniden, und Apteren der Vorwelt." Koch and Berendt. 1854.
5. "Fossil Spiders." 'Harvard University Bulletin,' vol. ii. 1882. Scudder.
6. "Systematische Uebersicht der fossilen Myriopoden, Arachnoideen

und Insecten." In Zittel's 'Handbuch der Palæontologie.' Bd. I., Abth. II. 1885. Scudder.

7. "Systematic Review of our present knowledge of Fossil Insects, including Myriapods and Arachnids." 'Bull. of the U.S. Geol. Survey,' vol. v. 1886. Scudder.
8. "Articulated Fossils of the Coal-Measures." 'Geol. Survey of Illinois,' vol. iii. 1868. Meek and Worthen.
9. "Einige Spinnen und ein Myriapode aus der Braunkohle von Rott." 'Verhandl. d. naturh. Vereins d. preuss. Rheinl.' Bd. V. 1878. Bertkau.
10. "On the discovery of a new and very perfect Arachnide from the Ironstone of the Dudley Coal-field" (*Eophrynus Prestvicii*). 'Geol. Mag.' 1871. Henry Woodward.
11. "Arthrolycosa." 'Amer. Journ. Sci. and Arts.' 1874. Harger.
12. "New species of Fossil Scorpions from the Carboniferous Rocks of Scotland and the English Borders." 'Trans. Roy. Soc. Edin.,' vol. xxx. 1882. Benjamin N. Peach.
13. "On a Silurian Scorpion from Gotland." 'Kongl. Vetenskaps-Akad. Handl.' Bd. XXI. 1885. Thorell and Lindström.
14. "Ancient Air-breathers." 'Nature.' 1885. Benjamin N. Peach.
15. "On a Fossil Scorpion from the Silurian Rocks of America." 'Bulletin of the Amer. Museum of Nat. Hist.,' vol. i. 1885. Whitfield.
16. "On a Chilognathous Myriapod from the Coal-Formation of Nova Scotia." 'Quart. Journ. Geol. Soc.,' vol. xvi. 1859. Dawson.
17. "On some Fossil Myriapods from the Lower Old Red Sandstone of Forfarshire." 'Proc. Roy. Phys. Soc. Edin.,' vol. vii. 1882. Benjamin N. Peach.
18. "On the Carboniferous Myriapods preserved in the Sigillarian stumps of Nova Scotia." 'Mem. Bost. Soc. Nat. Hist.,' vol. ii. 1873. Scudder.
19. "Archipolypoda, a subordinal type of spined Myriapods from the Carboniferous Formation." *Ibid.*, vol. iii. 1882. Scudder.
20. "The affinities of Palæocampa." 'Amer. Journ. Sci. and Arts.,' vol. xxiv. 1882. Scudder.
21. "Two new and diverse types of Carboniferous Myriapods." 'Mem. Bost. Soc. Nat. Hist.,' vol. iii. 1884. Scudder.
22. "On some Spined Myriapods from the Carboniferous Series of England." 'Geol. Magazine.' 1887. Henry Woodward.

CHAPTER XXXII.

ARTHROPODA—*continued.*

Class IV. Insecta.

The *Insecta* are defined as *Articulate animals in which the head, thorax, and abdomen are distinct; there are three pairs of legs borne on the thorax; the abdomen is destitute of legs; a single pair of antennæ is present; mostly, there are two pairs of wings on the thorax. Respiration is effected by tracheæ.*

The integument of the *Insecta*, in the mature condition, is more or less hardened by the deposition of chitine, and usually forms a resisting exoskeleton, to which the muscles are attached. The segments of the head are amalgamated into a single piece, which bears a pair of jointed feelers or antennæ, a pair of eyes, usually compound, and the appendages of the mouth. The segments of the thorax are also amalgamated into a single piece; but this, nevertheless, admits of separation into its constituent three somites (fig. 441). These are termed respectively, from before backwards, the "prothorax," "mesothorax," and "metathorax," and each bears a pair of jointed legs. In the great majority of Insects, the dorsal arches of the mesothorax and metathorax give origin each to a pair of wings.

Each leg consists of from six to nine joints. The first of these, which is attached to the sternal surface of the thorax, is called the "coxa," and is succeeded by a short joint, termed the "trochanter." The trochanter is followed by a joint, often of large size, called the "femur," succeeded by the so-called "tibia," and this has articulated to it the "tarsus," which may be composed of from one to five joints.

The wings of Insects are expansions of the sides of the meso- and meta-thorax, these expansions being supported by slender but firm tubes, known as the "nervures." Each nervure consists of a central trachea or air-tube, running in the centre of a larger blood-tube;

so that the wings not only act as organs of flight, but at the same time assist in the process of respiration. Normally, two pairs of wings are present, but one or other may be wanting.

The arrangement of the "nervures" of the wings is definite and characteristic in different groups of the Insects. In the most typical forms of wing, as in the *Orthoptera* (fig. 442, A), there are six principal veins, which arise, in groups of three, from two principal roots, one anterior and the other posterior. According to the nomenclature followed by Heer and Scudder, these six principal veins are termed, from before backwards, the *marginal*, *mediastinal*, *scapular*, *externomedian*, *internomedian*, and *anal* veins. The general arrangement of these veins (fig. 442, A) is as follows: "The *marginal* vein (*ma*) is placed at, or close to, the anterior margin of the wing; and "the 'mediastinal' and 'scapular' veins, which are superior (*i.e.*, part from the main vein on the upper or anterior side), terminate upon the anterior margin. The 'internomedian' and 'anal' take the opposite course, and their branches are inferior, or, at least, directed towards the inner margin; while the 'externomedian,' which is interposed between these two sets, terminates at the tip of the wing, and branches indifferently on either side" (Scudder). In some groups of the Insects there may be a suppression of certain of these six primary veins, and the above general arrangement is liable to characteristic modifications in different cases. The value of the characters derived from the neuration of the wings is, however, impaired by the fact that entomologists have not adopted a uniform nomenclature of the nervures in different orders of the *Insecta*.

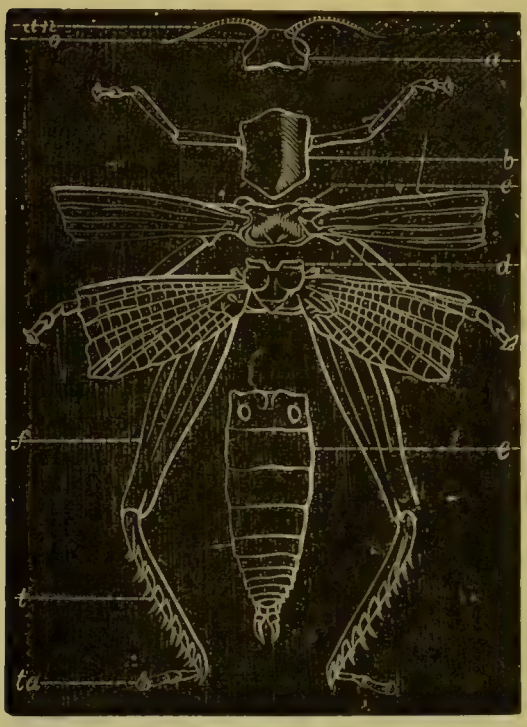


Fig. 441.—Diagram of the external anatomy of an Insect. *a*, Head carrying the eyes (*o*) and antennæ (*an*); *b*, First segment of the thorax, with the first pair of legs; *c*, Second segment of the thorax, with the second pair of legs and the first pair of wings; *d*, Third segment of the thorax, with the third pair of legs and the second pair of wings; *e*, Abdomen, without limbs, but carrying terminal appendages concerned in reproduction; *f*, Femur; *t*, Tibia; *ta*, Tarsus.

In the *Coleoptera* (Beetles) the wings of the anterior pair become

hardened by the deposition of chitine, so as to form two protective cases for the hinder membranous wings. In this condition the anterior wings are known as the "elytra," or "wing-cases." In some of the *Hemiptera* this change only affects the inner portions of the anterior wings, the apices of which remain membranous, and

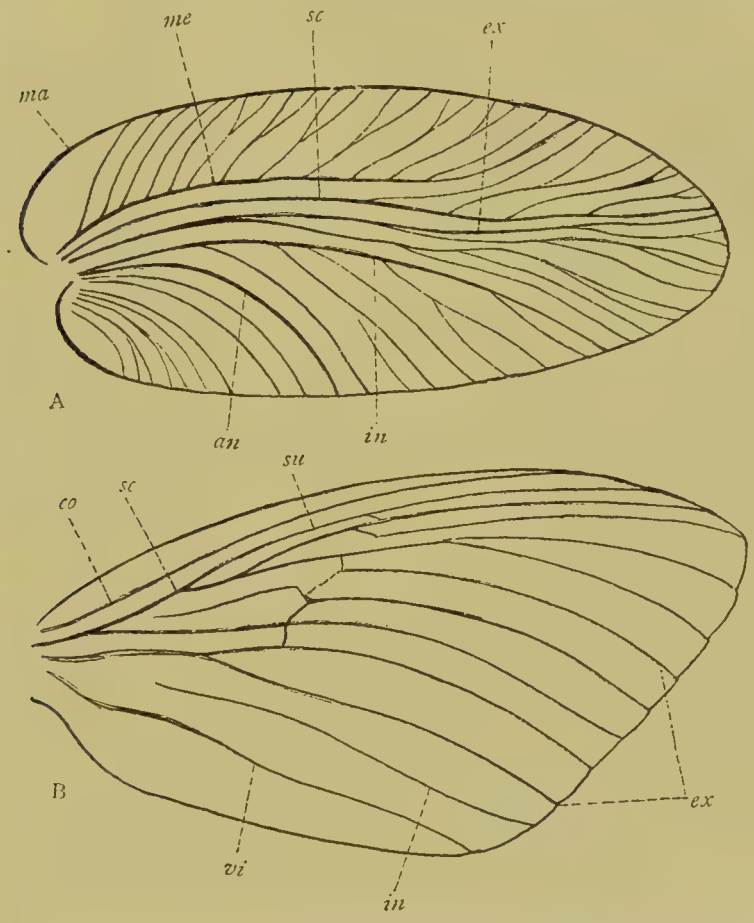


Fig. 442.—A, Schematic view of the right anterior wing of a Palæozoic Cockroach, greatly enlarged. (After Scudder.) *ma*, "Marginal" vein, which in this case merely thickens the margin of the wing; *me*, "Mediastinal" vein; *sc*, "Scapular" vein; *ex*, "Externomedian" vein; *in*, "Internomedian" vein; *an*, "Anal" vein. B, Anterior wing of Butterfly (*Castnia veraguana*), enlarged; *co*, "Costal" vein; *su*, "Subcostal" vein; *sc*, "Scapular" vein; *ex*, Branches of the "externomedian" vein; *in*, "Internomedian" vein; *vi*, "Internal" vein. (After J. O. Westwood.)

to these the term "hemelytra" is applied. In the *Diptera* the posterior pair of wings are rudimentary, and are converted into two capitate filaments, called "halteres" or "balancers." In the *Strepsiptera* the anterior pair of wings are rudimentary, and are converted into twisted filaments.

The typical number of somites in the abdomen of the *Insecta* is ten or eleven, and this number can sometimes be recognised in the *Orthoptera* and some other forms. In the *Hymenoptera* and *Lepidoptera* not more than nine or ten can be recognised, and in many cases even fewer can be made out. The abdominal somites are usually more or less freely movable upon one another, and never carry locomotive limbs. The extremity of the abdomen is, however, commonly furnished with appendages, which are connected with the generative function, and not infrequently serve as offensive and defensive weapons. Of this nature are the ovipositors of Ichneumons and other insects, and the sting of Bees and Wasps. In the Earwig (*Forficula*) these caudal appendages form a pair of forceps; whilst in many insects they are in the form of bristles, by which powerful leaps can be effected, as is seen in the Spring-tails (*Podurœ*).

Generally speaking, the young insect is very different in external characters from the adult, and it requires to pass through a series of changes, which constitute the "metamorphosis," before attaining maturity. In some Insects, however, there appears to be no metamorphosis, and in some the changes which take place are not so striking or so complete as in others. By the absence of metamorphosis, or by the degree of its completeness when present, Insects are divided into sections, called respectively *Ametabola*, *Hemimetabola*, and *Holometabola*, which, though not, perhaps, of a very high scientific value, are nevertheless very convenient in practice.

The "Ametabolic" Insects are those which have no proper "metamorphosis," the young stages of the Insect resembling the adult in all essential points except in size. This absence of a metamorphosis is only seen in Insects which are destitute of wings in the adult condition, and which are therefore often spoken of as the *Aptera*. In the so-called "Hemimetabolic" Insects, where an "incomplete" metamorphosis exists, the young insect is at first very different from the adult, and in the process of conversion into the latter it undergoes changes of form, while it at the same time remains capable of locomotion and of nourishing itself. In its first condition, after emergence from the egg, it is known as a "larva," and at this stage it presents no traces of wings. In its second condition—the stage of the "pupa"—it possesses rudimentary wings, but is still active and feeds. In its third stage, as the perfect insect or "imago," the wings are fully developed, and the insect acquires the power of flight. Lastly, the Insects which undergo a "complete" metamorphosis, and which are therefore said to be "holometabolic," pass through the same series of changes as those observed in the case of the Hemimetabolic forms, but the larva, pupa, and imago differ from one another more widely than is the case in the latter, and the insect in the "pupa" stage is quiescent and does not feed.

The great majority of existing Insects are terrestrial in habit, and almost all of those which are aquatic are inhabitants of fresh water. For these reasons, the remains of Insects are by no means abundantly preserved in the fossil condition, and are chiefly found in association with deposits of coal, or in lacustrine or fluviatile strata. Moreover, the remains of this class of Arthropods are generally found (except when preserved in amber) in a more or less fragmentary condition, and, under any circumstances, they cannot be satisfactorily deciphered except by practised workers in the department of Entomology. Between two and three thousand species of fossil Insects have been already described, but for the reasons just stated, it would be impossible here to deal with these in even a very general manner. The student desirous of acquiring a detailed knowledge of the fossil Insects must have recourse to special works on the subject, and, especially, to the admirable treatises published by Mr Scudder (see 'Literature of Insecta'). All that can be attempted here is to give a brief outline of the general geological distribution of the class, and of the leading characters and range in time of the great orders of *Insecta*.

As regards the general geological distribution of the *Insecta*, the oldest known insect is the *Palæoblattina Douvillei*, recently described by Brongniart from rocks belonging to the inferior portion of the Silurian (Upper Silurian) rocks of France. With the exception of this ancient type, the earliest remains of Insects are found in the Upper Devonian rocks of North America. "It is, however, only when we reach the productive Coal-measures that we arrive at insect-faunas of considerable extent, such as those especially of Commentry in France and of Mazon Creek in Illinois. Other considerable deposits are found in the Coal-fields of the Saarbrück and Wettin basins of Germany, the Belgian and British Coal-fields, and in America the Coal-basins of Nova Scotia and Pennsylvania. The Permian offers comparatively few species, but some of these are of particular interest (*e.g.*, *Eugereon*), and the Trias is almost wanting in fossil insects, except in the South Park of Colorado, where about twenty species have recently been obtained, affording transitional forms among the Cockroaches. Later Mesozoic deposits have yielded nothing in America, but much in England, where nearly all the strata from the Lower Lias to the Wealden have been productive. On the Continent of Europe prolific Liassic deposits have been discovered at Dobbertin in Germany and Schambelen in Switzerland, while the Oolitic beds of Solenhofen are world-renowned. Scanty returns have come from the Cretaceous, but the early Tertiaries have yielded an abundant harvest in the amber deposits of the Baltic shore, the marls of Aix, and in America at Florissant and Green River, while the Middle Tertiaries of Oeningen, Radoboj,

Parschlug, and Auvergne, and the Rhenish Brown Coals have been scarcely less prolific" (Scudder).

All the known Palæozoic Insects are referred by Mr Scudder to "a single homogeneous group of generalised Hexapods," which this eminent authority has named *Palæodictyoptera*, and which "should be separated from later types more by the lack of those special characteristics which are the property of existing orders than by any definite peculiarities of its own." With the exception of a few forms from the Trias of North America, which are allied to the Cockroaches, all the types included by Scudder under the name of *Palæodictyoptera* are restricted to the Palæozoic period. Of the modern orders of Insects, the great divisions of the *Orthoptera*, *Neuroptera*, and *Coleoptera* possess representatives in rocks of Triassic age; while the *Hemiptera*, *Diptera*, *Lepidoptera*, and *Hymenoptera* existed under well-marked forms in the Jurassic period.

In the following brief summary of the orders of Insects, with more especial reference to their geological history, Mr Scudder's treatise on fossil Insects in Zittel's 'Handbuch der Palæontologie' has been followed, with some variation as to the classification adopted :—

Division A. Ametabolic Insects.

Of the four existing orders of Ametabolic or Apterous Insects,—viz., the *Anoplura* ("Lice"), *Mallophaga* ("Bird-lice"), *Collembola* ("Springtails"), and *Thysanura*,—only the last two are known to be represented by fossil forms, and these only in deposits of Tertiary age. Thus, forms allied to the existing *Podura* and *Smynthurus* have been recorded as occurring in amber (early Tertiary), while a species of the recent genus *Lepisma* has been similarly preserved, along with a number of other allied but extinct types. The Oligocene deposits of Florissant, Colorado, have also yielded examples of insects belonging to the order *Thysanura*.

Division B. Hemimetabolic Insects.

Order I. Palæodictyoptera.—This order has been founded by Mr Scudder for the reception of a number of Palæozoic and a few Triassic Insects, with the following characters: "Body generally elongated, mouth-parts variously developed; antennæ filiform. Thoracic joints subequally developed; legs moderately long. Mesothoracic and metathoracic wings closely similar, equally membranous; the six principal veins (fig. 442, A) always developed, the marginal simple, and forming the costal border, the mediastinal simple, or with superior branches only; the other veins usually

dichotomise; stout and well-defined cross-veins rare; membrane generally reticulate. Wings in repose lying on the abdomen, the anal area of the hind-wings, though usually of great distal extension, never plaited, though sometimes broadly folded. Abdomen usually long and slender, the last joint often furnished with simple articulated appendages" (Scudder).

The *Palæodictyoptera*, as above defined, comprise generalised Insects, in which there was an "incomplete" metamorphosis, and the four wings were membranous, equally developed, and characterised by a simple type of neuration. Mr Scudder recognises within the limits of the *Palæodictyoptera* four principal types of structure, representing the existing orders of the *Orthoptera*, *Neuroptera*, *Hemiptera*, and *Coleoptera*, and in accordance with this he has divided the order into four primary groups (the Orthopteroid, Neuropteroid, Hemipteroid, and Coleopteroid groups). The earliest known form of the *Palæodictyoptera* is the *Palæoblattina Douvillei* of the Silurian rocks of Calvados, which is at present the most ancient representative of the entire class of the Insects, and the affinities of which are uncertain. Other forms of the order appear in the Upper Devonian rocks of North America; numerous Carboniferous and a few Permian forms are known; and the last representatives of the order appear in the Triassic rocks of North America.

The Orthopteroid section of the *Palæodictyoptera* includes a group of forms representing the modern Cockroaches, and a second group which shows relationships to the existing "Stick-insects" (*Phasmidæ*). Apart from the Silurian genus *Palæoblattina*, various Carboniferous types are known which are allied to the existing Cockroaches, but differ from these in the neuration of the wings; and upon such have been founded the genera *Archimylacris*, *Mylacris*, *Progonoblattina* (fig. 443), *Etoblattina*, &c. Of these, the last-mentioned genus occurs also in the Trias of North America, along with other allied forms. The precursors of the modern *Phasmidæ* are the "Protophasmids" of the Carboniferous rocks, comprising various genera which resemble the existing "Stick-insects" in the form of

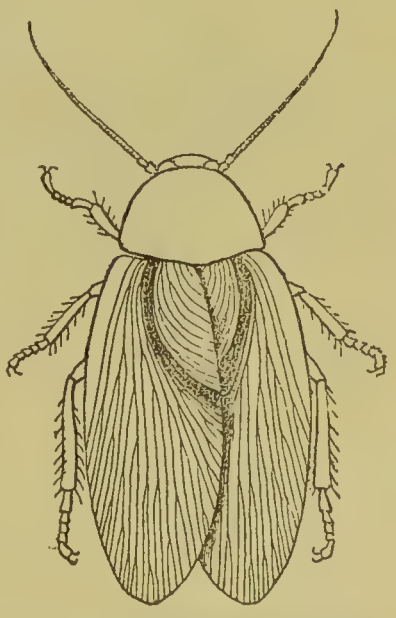


Fig. 443.—*Progonoblattina helvetica*, an Orthopteroid type of the *Palæodictyoptera*, from the Carboniferous rocks of Switzerland, restored. (After Heer.)

the body, but in which the wings have the characteristic features of those of the *Palæodictyoptera* generally, being equally developed, with a simple neuration, the anterior pair being unthickened and transparent. The two best known genera of this group are *Titano-*

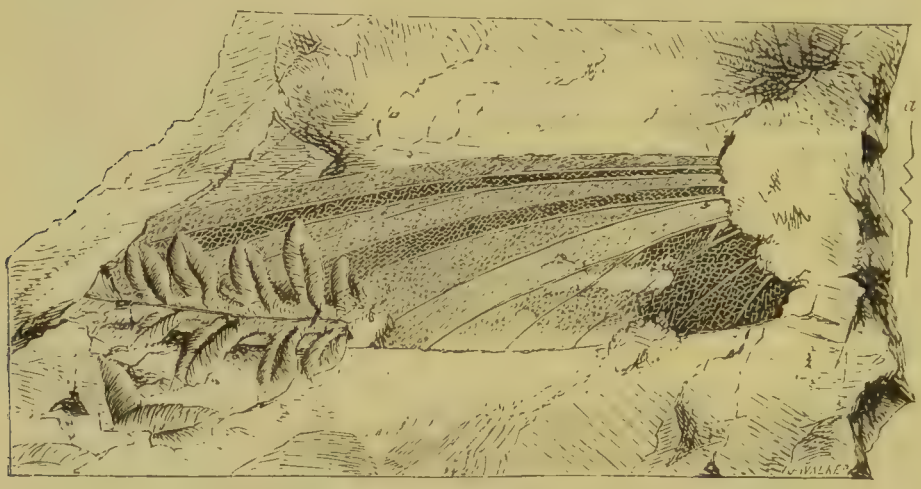


Fig. 444.—*Haplophlebium Barnesii* (after Dawson). From the Carboniferous rocks of Canada. *a*, Profile of base of wing.

phasma and *Protophasma*, both from the Carboniferous rocks. The same formation has also yielded a number of other allied types, upon which have been founded the genera *Dictyoneura*, *Haplophlebium* (fig. 444), *Paolia*, *Breyeria*, &c.

The Neuropteroid section of the *Palæodictyoptera* includes a number of Palæozoic insects, which appear upon the whole to be most nearly allied to the existing May-flies (*Ephemeridæ*). The most ancient types of this section appear in the Upper Devonian rocks of Canada, and upon these have been founded the genera *Platephemera* (fig. 445), *Homothetus*, *Xenoneura*, and *Lithentomum*. A number of allied types, which have been referred to such genera as *Miamia*, *Lithomantis*, *Hemeristia*, &c., have been detected in the Coal-measures of both Europe and North America.



Fig. 445.—Wing of *Platephemera antiqua*, from the Upper Devonian rocks of Canada. (After Dawson.)

Of the Hemipteroid section of the *Palæodictyoptera* the most remarkable type is the Permian genus *Eugereon* (fig. 446). In this remarkable genus the mouth-organs are lancet-shaped, the antennæ are slender and many-jointed, and the front and hind wings are

of large size, transparent, and essentially similar in form and neuration. The Permian genus *Fulgorina* is allied to the preceding; whereas in the *Phthanocoris* of the Coal-measures, the front wings differ in character from the hind wings, and assume the features of "hemelytra."

Lastly, Mr Scudder forms a section of "Coleopteroid" *Palæodictyoptera* for the reception of Palæozoic insects, which may be regarded as precursors of the modern Beetles (*Coleoptera*), and



Fig. 446.—*Eugereon Böckingi*, from the Lower Permian rocks of Germany. (After Dohrn—copied from Zittel)

which resemble the latter in having the anterior pair of wings hardened by chitine so as to form cases ("elytra") for the protection of the membranous hind-wings. The existence of insects of this type in the Carboniferous period is shown by the presence in fossil wood from the Coal-measures of borings similar to those produced by existing Beetles. The elytra of Coleopteroid insects have also been recently discovered in the Carboniferous rocks of Silesia, but the characters of these have not yet been fully determined.

Order II. Rhynchota (*Hemiptera*).—*Mouth suctorial, beak-shaped, consisting of a jointed rostrum, composed of the elongated labium and labial palpi, which together form a jointed, tubular sheath*

for the bristle-shaped, styliform mandibles and maxillæ. Eyes compound, usually with ocelli as well. Two pairs of wings in most; sometimes wanting. Pupa generally active.

The recent *Rhynchota* are of very varied habit, and they may be divided into two principal sections in accordance with the structure of the wings. In one great section of the order (*Homoptera*) the anterior and posterior wings are both membranous, the former being simply of firmer texture than the latter. To this section belong such existing types as the Aphides, the Cicadas (fig. 447, C), the Lantern-flies, &c. In the other great section of the order (*Heteroptera*) the anterior wings are hardened at their bases by chitine and remain membranous towards their apices (fig. 447, B), constituting

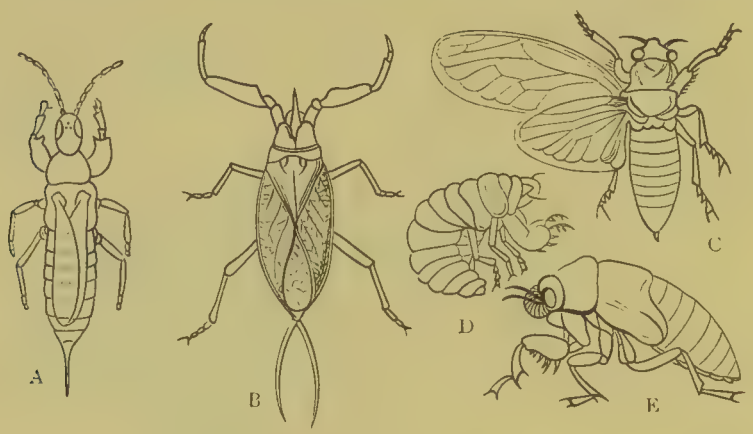


Fig. 447.—Recent Rhynchota. A, *Thrips*, enlarged; B, *Nepa cinerea*, enlarged; C, *Cicada Anglica*, the wings on the right side of the body being omitted; D, Larva of the same; E, Pupa of the same. (Figs. C, D, and E are after Westwood.)

protective cases ("hemelytra") for the wholly membranous hind wings. In this section are included the numerous forms of Land-bugs and Water-bugs.

As regards their geological distribution, the place of the *Rhynchota* in the Palæozoic rocks is taken by the Hemipteroid forms of the *Palæodictyoptera*. In the Jurassic rocks, however, appear for the first time well-marked representatives of both the above-mentioned sections of the order; the Homopterous forms being represented by types allied to the Cicadas, while the Heteropterous division is represented by forms closely allied to, or identical with, the existing Water-scorpions (*Nepa*) and the Land-bugs. The little Plant-lice (*Aphis*, &c.) appear in the Cretaceous rocks (Wealden); and a vast number of Tertiary types of the *Rhynchota* have been described, most of these presenting no marked peculiarities as compared with living types. The *Palæontina oolitica* of the Stonesfield Slate of

England, regarded by Mr Butler as being a Butterfly, is considered by Mr Scudder as truly a Cicada.

Order III. Orthoptera.—In this order *the mouth is masticatory; the wings are four, sometimes wanting, the anterior pair mostly smaller than the posterior and of a semi-coriaceous or leathery consistence. The posterior wings, when not in use, are plaited longitudinally like a fan or may be transversely folded. The interspaces between the nervures are filled with transverse reticulations, and the anal area of the wing is of large size. The antennæ are usually filiform, and the females are usually provided with an ovipositor.*

The earliest types of the *Orthoptera* appear in the Trias, where the order is represented by several forms of Cockroaches. In the Jurassic rocks are found forms belonging to the families of the Earwigs (*Baseopsis*, of the Lias), the Locusts (*Gryllacris* and *Locusta*), and the Crickets (*Gryllus*), while the Grasshoppers (*Acrididæ*) are doubtfully represented in deposits of Mesozoic age. All the preceding families continue to be well represented in the Tertiary rocks, and in deposits of this age appear also forms belonging to the families of the *Mantidæ* and *Phasmidæ*.

Order IV. Neuroptera.—*Mouth usually masticatory; wings four in number, all membranous, generally nearly equal in size, traversed by numerous delicate nervures, which have a longitudinal and transverse direction, thus giving them a reticulated, lace-like aspect* (fig. 448). *Metamorphosis in some groups incomplete, in other groups complete. The larva active, hexapod, the pupa active or quiescent.*

The insects included in the order *Neuroptera* differ so widely in their characters, habits, and metamorphoses that they may be divided into the three primary groups of the *Pseudoneuroptera*, the *Neuroptera vera*, and the *Trichoptera*, of which the first constitutes a transitional group between the typical *Neuroptera* and the *Orthoptera*.

The *Pseudoneuroptera* are characterised by their incomplete metamorphosis, the larvæ being commonly inhabitants of water, and the pupæ being active. Of the groups included in this section of the order, the Termites or "White Ants" are represented in rocks as old as the Lias, and abounded in Tertiary times. The May-flies (*Ephemeridæ*) and the Dragon-flies (*Libellulidæ*) likewise commenced their existence in the Jurassic rocks, and have many Tertiary representatives. Beautifully preserved examples of the Dragon-flies have been yielded by the fine-grained Lithographic Slates of Solenhofen (fig. 448), while still older forms have been recognised in the Lias. Lastly, the family of the *Perlidæ*, including the recent "Stone-flies," is represented in the Eocene Tertiary.

The group of the *Neuroptera vera* includes those members of

the order in which there is a complete metamorphosis, the pupa being inactive, and comprises the Ant-lions (*Myrmeleontidæ*), the Aphis-lions (*Hemerobiidæ*), the Scorpion-flies (*Panorpidæ*), and the *Sialidæ*. The first of these groups is doubtfully known by fossil forms in the Tertiary rocks, but the three last have representatives in the Jurassic rocks, and are also found more or less abundantly in deposits of Tertiary age.

Lastly, the group of the *Trichoptera* comprises the Caddis-flies (*Phryganeidæ*), in which the anterior wings are generally hairy, the larvæ are aquatic and usually reside in tubular cases formed of



Fig. 448.—*Petalia longialata*, a fossil Dragon-fly from the Lithographic Slates (Jurassic) of Solenhofen. (Copied from Scudder and Zittel.)

small foreign bodies, and the pupæ are inactive during the greater part of their life. A few Mesozoic forms of the Caddis-flies are known, and various Tertiary types have been recognised. The principal palæontological interest of the Caddis-flies arises, however, from the fact that the tubular cases of the larvæ, formed of small fragments of stone or of minute shells cemented together, are capable of preservation in the fossil state. Such cases have been found in the Cretaceous rocks of Bohemia and in various Tertiary deposits, and they sometimes occur in such numbers as to give rise to deposits of considerable thickness. Of this nature is the so-called "Indusial Limestone" of Auvergne, which covers considerable areas, and attains a thickness of eight or ten feet.

Division C. Holometabolic Insects.

Order I. Aphaniptera.—*Wings rudimentary, in the form of scales situated on the mesothorax and metathorax. Mouth suctorial. Metamorphosis complete.*

This order includes only the Fleas, and requires no further consideration here, since no fossil representatives of the group are known to exist.

Order II. Diptera.—This order includes the "Two-winged Flies," and is characterised by the fact that *the mouth is suctorial and is also adapted for piercing; the anterior wings are membranous, with a small basal lobe* ("*alula*"), *not closely reticulated, but with a few, definitely-placed cross-veins. The posterior wings are rudimentary, and are represented by a pair of clubbed filaments* ("*halteres*").

As regards the distribution of the *Diptera* in time, a few representatives of the order have been detected in rocks as old as the Jurassic, but the majority of the fossil forms are found in Tertiary deposits, being especially abundant in amber. Most of the existing families of *Diptera* are represented by fossil forms, but none of these present any points of special interest.

Order III. Lepidoptera.—This order includes the Butterflies and Moths, and is characterised by the fact that *the mouth of the adult is completely adapted for suction, the mandibles being rudimentary. Both pairs of wings are present, and are membranous, being covered with rows of flattened hairs or scales. The neuration of the wings* (fig. 442, B) *is simple, the nervures being rarely united by cross-veins. The "marginal" vein is wanting; while the "scapular" and "externomedian" veins generally form between them a median cell, and give origin to most of the secondary nervures. The metamorphosis is complete, the larva* ("*caterpillar*") *being worm-like, and the pupa* ("*chrysalis*") *being completely enclosed in a horny integument.*

As regards their distribution in time, undoubted remains of several species of *Lepidoptera* (such as the *Sphinx Snelleni* of the Solenhofen Slates) have been detected in the Jurassic rocks; and the tunnels of the larvæ of small Moths have been noticed in fossil leaves of Cretaceous age; but the number of recognised Mesozoic Lepidoptera is very limited. In the Tertiary rocks the remains of *Lepidoptera* are still exceedingly rare, but both the Moths and the Butterflies are now represented by fossil forms. About a dozen Tertiary species of Butterflies are known altogether, and most of these belong to extinct genera (*Mylothrites*, *Neorinopsis*, &c.)

Order IV. Hymenoptera.—This order includes the Ants, Bees and Wasps, Gall-flies, &c., and is characterised by the fact that *the mouth-organs are adapted partly for suction and partly for biting, the mandibles being well developed. Both pairs of wings are usually*

present, the front pair being larger than the hinder pair. The wings are membranous, with a few distant nervures, which are generally connected by cross-veins so as to form large polygonal cells. The females usually with an ovipositor, which may be converted into a "sting" (aculeus).

As regards their distribution in time, very few fossil forms of the *Hymenoptera* are known in deposits older than the Tertiary. Of the very limited number of Mesozoic forms one of the most ancient is the *Palæomyrmex prodromus*, described by Heer from the Liassic rocks of Switzerland, which belongs to the family of the Ants (*Formicidæ*), a family which has also representatives in later Jurassic deposits. In the Tertiary rocks the remains of *Hymenoptera* are more abundant, almost all the existing families of importance being represented; but none of the fossil forms are of special interest.

Order V. Strepsiptera.—*Females without wings or feet, parasitic. Males possessing the posterior pair of wings, which are large, membranous, and folded longitudinally like a fan. The anterior pair of wings rudimentary, represented by a pair of singular twisted organs. Jaws rudimentary.*

The *Strepsiptera* constitute a small order, which includes certain minute parasites of Bees and other *Hymenoptera*. The females are grub-like, but the males are winged. A single example of one of the winged males of this singular group of insects has been detected in amber, and has been referred to the extinct genus *Triæna*.

Order VI. Coleoptera.—This great order of Insects includes the "Beetles," which are characterised by their strong chitinous integument and the complete adaptation of the mouth-organs for biting, the mandibles being well developed. *The anterior wings are useless as organs of flight, and are hardened by chitine, so as to form protective cases (elytra) for the posterior wings, these being membranous, and being folded transversely and longitudinally in repose. The nervures of the hind-wings are few and distant, cross-veins being rarely developed. The inner margins of the elytra* (fig. 449) *are generally straight, and when in contact they form a longitudinal suture.*

As regards their distribution in time, the oldest types of the *Coleoptera*, recognised by Mr Scudder, belong to the *Curculionidæ* (Weevils), and appear in the Triassic rocks (*Curculionites prodromus*). The Jurassic rocks have yielded a number of types of this family also; while Heer describes other forms from the Cretaceous rocks of Greenland; and about one hundred species of Weevils, belonging mostly to existing genera, have been mentioned or described from the Tertiary rocks. The great existing families of the *Chrysomelidæ*, *Buprestidæ*, and *Carabidæ* (fig. 449, B) are also all represented by Triassic forms; and all have more or less numerous Jurassic and Tertiary representatives. Of the remaining

families of the *Coleoptera* the majority of the leading groups of the present day, such as the *Tenebrionidæ*, *Cerambycidæ*, *Scarabæidæ*, *Elateridæ*, *Staphylinidæ*, *Coccinellidæ*, *Hydrophilidæ*, and *Dytiscidæ* possess more or less numerous Jurassic representatives, and all

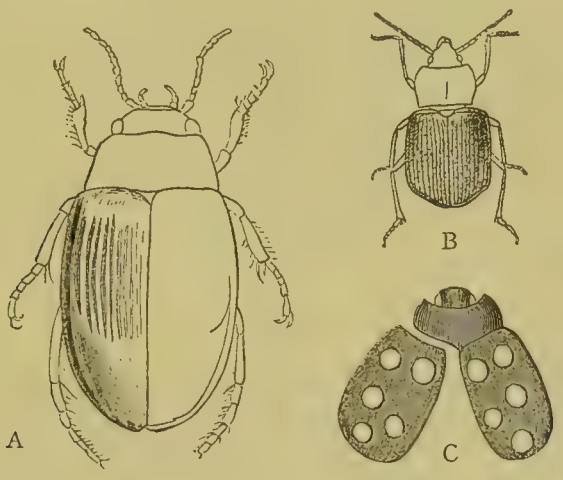


Fig. 449.—A, *Dytiscus Lavateri*, restored, from the Miocene deposits of Oeningen, of the natural size; B, *Thurmannia punctulata*, one of the *Carabidæ*, restored, and enlarged three times, from the Lias of Schambelen; C, *Coccinella decempunctata*, enlarged twice, from the Miocene deposits of Oeningen. (After Heer.)

occur under many specific forms in the Tertiary rocks. Many of the smaller families of Beetles are also known by fossil forms, but the order has attained its maximum development at the present day.

LITERATURE.

1. "Insecta," in Zittel's 'Handbuch der Palæontologie,' Bd. II., Lief. 5. 1885. Scudder.
2. "Systematic Review of our present Knowledge of Fossil Insects." 'Bull. of the U.S. Geol. Survey.' No. 31, 1886. Scudder.
3. "The Tertiary Lake-basin at Florissant." 'Bull. U.S. Geol. Survey of the Territories,' vol. vi. 1881. Scudder.
4. "Winged Insects from a palæontological point of view, or the Geological History of Insects." 'Mem. Bost. Soc. Nat. Hist,' vol. iii. 1885. Scudder.
5. "Die Insecten und Spinnen der Vorwelt." 1856. Giebel.
6. "A History of the Fossil Insects in the Secondary Rocks of England." 1845. P. B. Brodie.
7. "Die fossilen Insecten der Kohlenformation von Saarbrücken." Von Goldenberg. 'Palæontographica.' 1854.
8. "Eugereon Böckingi, eine neue Insectenform, aus dem Todtliegende." Dohrn. 'Palæontographica.' 1866.
9. "Die Insectenfauna der Tertiärgebilde von Oeningen und von Radoboj in Croatien." 1847-53. Oswald Heer.

10. "Die Urwelt der Schweiz." 2d Ed. 1879. English translation. 1876. Oswald Heer.
11. "Aperçu sur les insectes fossiles en général." 2d. Ed. 1883. Charles Brongniart.
12. "Lebenszeichen vorweltlicher im Bernstein eingeschlossener Thiere." 1856. Menge.
13. "Descriptions of Fossil Insects found at Mazon Creek." 'Geol. Survey of Illinois,' vol. iii. 1868. Scudder.
14. "The Devonian Insects of New Brunswick." 'Anniv. Mem. Bost. Soc. Nat. Hist.' 1880. Scudder.
15. "The Carboniferous Hexapod Insects of Great Britain." "Mem. Bost. Soc. Nat. Hist.' 1883. Scudder.
16. "Palæodictyoptera, or the Affinities and Classification of the Palæozoic Hexapoda." Ibid. 1886. Scudder.
17. "New Genera and Species of Fossil Cockroaches from the older American Rocks." 'Proc. Acad. Nat. Sci. Philadelphia.' 1885. Scudder.
18. "On a remarkable Fossil Insect from the Coal-Measures of Scotland." 'Quart. Journ. Geol. Soc.,' vol. xxxii. 1876. Henry Woodward.
19. "On some New British Carboniferous Cockroaches." 'Geol. Magazine.' 1887. Henry Woodward.
20. "Die Ahnen unserer Schmetterlinge in der Secundär- und Tertiärperiode." 'Berl. Entom. Zeitschr.,' Bd. XXIX. 1885. Oppenheim.

CHAPTER XXXIII.

MOLLUSCOIDEA.

Polyzoa.

We may consider here, under the name of *Molluscoidea*, the two groups of animals which are known respectively as the *Polyzoa* and the *Brachiopoda*. These two groups, in many respects closely allied to one another, present affinities on the one hand to the Worms, and on the other hand to the *Mollusca*, with both of which they have been arranged by different systematists. In the present state of our knowledge, however, it seems best to consider these two groups separately, without referring them definitely to either of the two sub-kingdoms above mentioned. The Tunicates, which have also often been included amongst the Molluscoids, may likewise be in the meanwhile regarded as a separate division, which finds its most natural position between the *Mollusca* and the *Vertebrata*. It is not necessary, however, to further consider the Tunicates in this work, since the palæontological history of this group of animals is an almost absolute blank. No fossil remains of Tunicates have, in fact, been hitherto discovered except the minute spicules of a species of *Leptoclinum* in the Pliocene beds of St Erth. Many existing Tunicates, however, both simple and compound, are known to possess more or less numerous calcareous spicula in their tissues, and by the help of these it may ultimately be found possible to trace back the existence of these singular organisms to an earlier period of the earth's history.

The *Molluscoidea* may be briefly defined as unsegmented, simple or compound animals, with bilateral symmetry. The mouth is furnished with a crown of ciliated tentacles, or with spirally-rolled ciliated processes. The nervous system consists of a single ganglion, or of an œsophageal nerve-ring with more than one ganglion. A heart is absent or present. Under this head may be placed the two classes of the *Polyzoa* and the *Brachiopoda*.

Polyzoa.

Class I. Polyzoa (*Bryozoa*).—The members of this class are mostly *composite animals, each zoöid of which possesses, typically, a freely suspended alimentary canal, with mouth and anus, enclosed within a double-walled sac. The mouth is surrounded with a circle or crescent of hollow ciliated tentacles, and the nervous system consists of a single ganglion placed between the mouth and the anus.*

With the single exception of the genus *Loxosoma*, all the *Polyzoa* live in an associated form in colonies or "polyzoaria," which are sometimes foliaceous, sometimes branched and plant-like, sometimes laminar, sometimes encrusting, and very rarely are free. Each "polyzoarium" consists of an assemblage of distinct but similar zoöids arising by continuous gemmation from a single primordial individual. The entire colony—or its entire dermal system—is called the "polyzoarium" or "cœnœcium"; the separate zoöids are called "polypides"; and the little chambers in which each is contained are called the "cells," or "zoœcia."

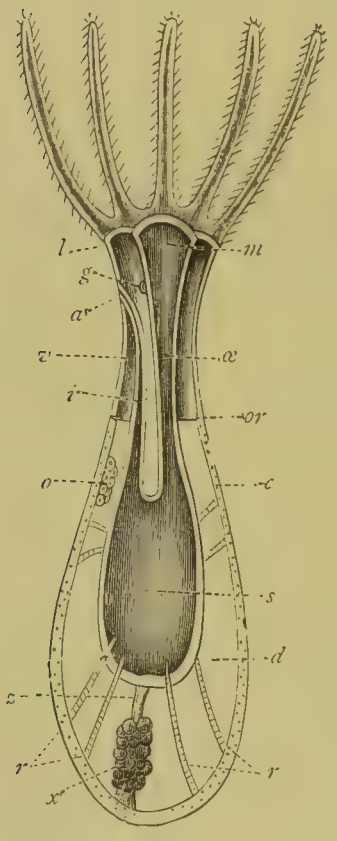


Fig. 450.—Diagram showing the structure of a single polypide of a Polyzoan (after Busk). *l*, Tentacles; *m*, Mouth; *g*, Nerve-ganglion; *œ*, Gullet; *s*, Stomach; *i*, Intestine; *a*, Anus; *o*, Ovary; *x*, Testis; *z*, Funiculus; *or*, Aperture of the zoœcium; *v*, Tentacular sheath; *d*, Perivisceral cavity; *r*, Retractor muscles; *c*, Ectocyst.

A typical polypide of a *Polyzoön* (fig. 450) consists of a membranous sac ("endocyst") the external surface of which, except at its anterior end, is generally hardened by an investing horny or calcified layer, which is known as the "ectocyst." Freely suspended in the perivisceral fluid filling the space enclosed within the endocyst is the alimentary canal, which consists of a mouth, gullet, stomach, intestine, and anus. The mouth (fig. 450, *m*) is placed anteriorly, and is surrounded by a crown of tubular, non-retractile tentacles, which are ciliated, and act as respiratory organs. In different types of the class, the tentacles are arranged in a circle or are disposed so as to form a horse-shoe or crescent. The alimentary canal is bent upon itself in such a way that the anus (fig. 450, *a*) comes to be placed near the mouth, being usually placed outside the tentacular circle

(in the "Ectoproctous" *Polyzoa*), but sometimes within it (in the "Entoproctous" *Polyzoa*). The alimentary canal is moored to the body-wall by muscular bands, those springing from the bottom of the cell serving to retract the polypide within its chamber, while the protrusion of the tentaculated anterior extremity is effected by muscular fasciculi which run in a circular manner in the wall of the cell.

Each polypide possesses a single nervous ganglion (fig. 450, *g*), which is placed upon one side of the gullet, between it and the anal aperture. The different polypides may also be connected together by a remarkable organic structure, which was at one time believed to be of a nervous nature, and was termed the "colonial nervous system," but which is now generally spoken of as the "endosarc." This singular connective system, by which the different polypides of the colony are organically united, commences as a peculiar cellular cord, the "funiculus" (fig. 450, *z*), which stretches from the base of the stomach to the bottom of the zoœcium, and upon which the testis is developed. At the point where the funiculus is fixed to the bottom of the cell, a perforation in the ectocyst exists, and filaments of the funiculus thus either pass into adjacent polypides, or become connected with a common branched fibre which runs through the stolons of the colony (as in *Bowerbankia*). In many cases the endosarcal cords give off branching fibres, and they have a general likeness to a nervous system. Histologically, however, the endosarc does not consist of nervous elements, and it may be regarded as a kind of cœnosarcal structure, which is largely connected with the production of the generative elements, and from which, possibly, the polypides are produced by gemmation.

The polypide of the *Polyzoa* is generally hermaphrodite, the ovary (fig. 450, *o*) being usually situated near the summit of the cell, attached to the inner surface of the endocyst, while the testis (*x*) is placed at the bottom of the cell, and is attached to the "funiculus." The generative elements are usually set free into the perigastric space, the ova being thus fecundated within the body-cavity of the parent polypide. The fertilised ova may pass into special dilatations of the cell ("ovicells"), or the embryos may be hatched within the perivisceral cavity of the parent.

The embryo is, to begin with, ciliated and freely locomotive, but ultimately fixes itself, and, except in *Loxosoma*, begins to produce a colony by means of budding. The new buds are usually produced from the dorsal wall of the polypide, or from its sides, or sometimes from its anterior extremity. Fission, so common among the Cœlenterates, has never been noticed to occur. The ultimate form of the polyzoary depends upon the precise method in which the new buds are developed. The separate polypides of the colony are ap-

parently always more or less clearly united with one another by an organic connection. In many cases this communication between the different polypides is effected by means of the structure which has been previously spoken of as the "endosarc." In other cases the walls of the cells are pierced by pores or traversed by tubuli, by means of which the perivisceral cavities of adjoining polypides are placed in communication. In other cases, again, there exists a common lamina, the extension of which precedes the production of new cells. Lastly, in the group of *Polyzoa* known as the *Ctenostomata*, there exists a common tube with which all the polypides of the colony are connected.

The structures in the *Polyzoa* with which the palæontologist is more especially concerned are those developed from the external

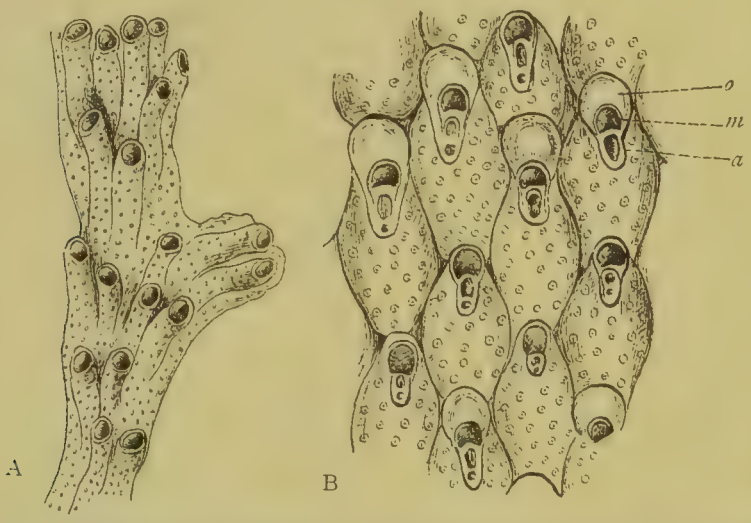


Fig. 451.—A, Fragment of *Stomatopora* (*Alecto*) *dilatans*, a recent Cyclostomatous Polyzoön, enlarged. B, A few cells of *Smittia Marionensis*, a recent Cheilostomatous Polyzoön, enlarged: *m*, Aperture of the cell; *a*, Avicularium; *o*, Ovicell. (After Busk.)

investing layer or "ectocyst," which form the skeleton of the colony, and which alone are capable of being preserved in the fossil condition. In rare cases among the existing *Polyzoa* the ectocyst may be absent, or may be gelatinous in consistence; but it is usually either purely chitinous or more or less extensively calcified. The ectocyst forms for each polypide of the colony a more or less complete "cell"; but the cell is invariably furnished at one point with an "aperture" or "mouth," whence the polypide can protrude its tentaculate head. In various forms, however, the anterior wall of the ectocyst may be imperfectly hardened, or may remain membranous. The form of the "cells" or "zoœcia" in the *Polyzoa* varies extremely in different groups, and important distinctions are

based upon this character. Thus, in the so-called "Cyclostomatous" Polyzoa the cells are tubular in form (fig. 451, A), and the aperture is terminal in position, and is approximately equal to the cell itself in diameter, while there is no special movable apparatus for its closure. On the other hand, in the so-called "Cheilostomatous" Polyzoa (fig. 451, B) the mouth of the cell is never quite terminal in position, but is always placed upon the front of the cell, generally close to the anterior end, while its diameter is less than that of the cell, and it is provided with a movable opercular valve.

The surface of the cell may be "either smooth and entire, spinous or granulous; perforated with minute pores, or cribriform with larger openings; reticulate or ribbed, &c.,—all of which conditions, with certain precautions, afford excellent diagnostic characters" (Busk). The margins of the mouth of the cell, also, may be "simple or thickened, unarmed or beset with erect 'marginal spines,' which again may be either rigid or articulated at the base, simple or branched."

Though the separate zoœcia of a Polyzoan colony are usually apparently quite separate and distinct from one another, except by continuity of their external investment, it has been shown that contiguous cells are commonly placed in direct connection with

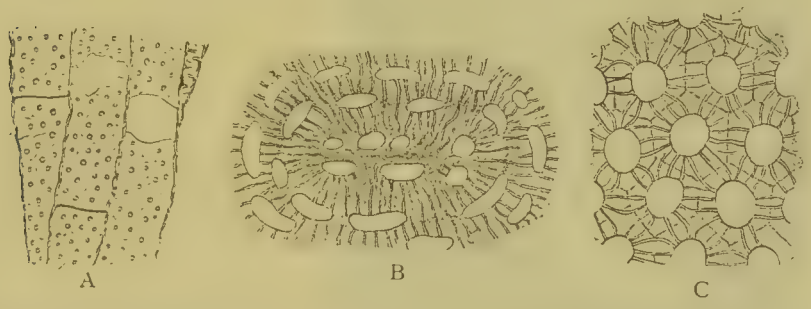


Fig. 452.—A, Longitudinal section of a few tubes of the recent *Tennysonia stellata*, enlarged, showing the porous walls of the cells; B, Central portion of a transverse section of a branch of *Cellepora ramulosa* (Recent), showing tubes connecting the cavities of adjoining cells, enlarged; C, Part of a tangential section of the polyzoary of *Domopora stellata* (Recent), enlarged to show the connecting-tubuli. (Original.)

one another by what have been called "communication-plates" or "rosette-plates." These are portions of the cell-wall pierced by one or more minute pores which transmit processes of the structure which has been previously described as the "endosarc." In many of the calcareous *Polyzoa* also, the walls of the cells are pierced by more or less numerous pores, which open into the cavity of the cell (fig. 451). In certain of the Cyclostomatous *Polyzoa*, as also in some Cheilostomatous forms, where the walls of the cells are of considerable relative thickness, these pores assume

the form of tubes, which place the perivisceral cavities of contiguous cells in direct communication, as is seen, for example, in such recent genera as *Cellepora* among the *Cheilostomata*, and *Domopora* and *Heteropora* among the *Cyclostomata*. These connecting-tubes (fig. 452) are usually wide and trumpet-shaped at the points where they open into the cavities of the cells, and are contracted in the middle portion of their course; and they, doubtless, are simply a further development of the simple pores seen in many other forms.

Again, in various of the Palæozoic *Polyzoa*, and particularly in the family of the *Fenestellidæ*, a portion of the polyzoary consists of dense calcareous tissue which exhibits under the microscope a finely punctated appearance. When sufficiently thin sections of this punctated layer are prepared, and examined with a sufficiently high magnifying power, the tissue is seen to be penetrated by innumerable exceedingly minute tubuli (fig. 453), which run at right angles to the surface of the polyzoary. Nothing certain has, however, been ascertained as to the nature and function of these tubuli. In some types, such as *Rhombopora* (*Ceriopora*) *interporosa*, of the Carboniferous rocks, the thickened walls of the cells near their mouths are penetrated by dark rod-like structures which run at right angles to the surface. These structures are of larger size than the tubuli of the Fenestellids, but they sometimes exhibit a clear central space, and it is probable that they are really of the nature of tubes.

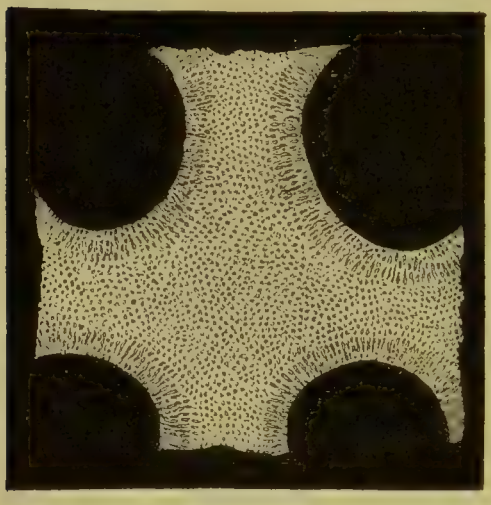


Fig. 453.—A portion of the punctated layer on the non-poriferous side of a Fenestellid (*Phyllopora* sp.), cut parallel with the surface and greatly enlarged. Devonian, Canada. (Original.)

In a great number of the recent *Polyzoa*, the polyzoarium is furnished with singular appendages, which are known as "avicularia" and "vibracula," and which are to be regarded as specially modified zoöids. The avicularia or "bird's-head processes" (fig. 454, B and C) differ a good deal in shape, but consist essentially of "a movable mandible and a cup furnished with a horny beak, with which the point of the mandible is capable of being brought into apposition" (Busk). In shape, the avicularia often closely resemble the head of a bird; and they are in many respects comparable with the "pedicellariæ" of the *Echinodermata*, keeping up a constant snapping movement which continues long

after the death of the general colony. In the "vibracula" (fig. 454, A), the place of the mandible of the avicularium is taken by a bristle, or seta, which is capable of extensive movement.

Owing to the minute size of the avicularia and vibracula and their readily perishable structure, it could hardly be expected that the fossil *Polyzoa* should exhibit similar organs except under the most favourable conditions of preservation; and as a matter of fact, these appendages have not hitherto been recognised except in a few instances. The former existence of avicularia may, however, be in many cases inferred by the presence of cicatrices or pore-like

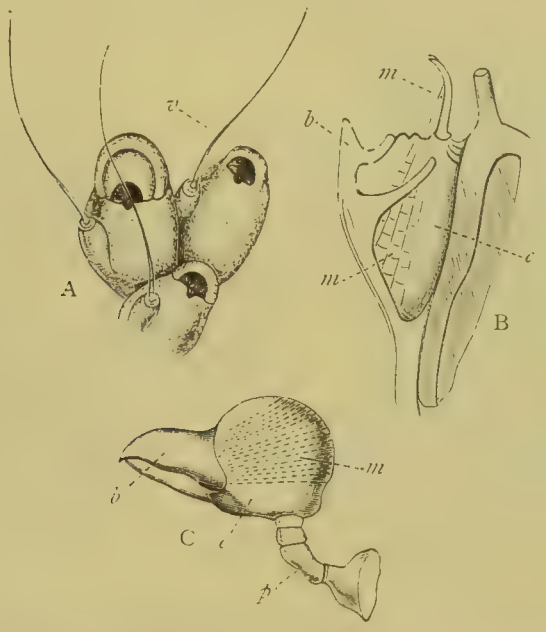


Fig. 454.—A, Three cells of *Mastigophora Hyndmanni*, showing vibracula (*v*)—the left-hand cell also shows an oœcium; B, Sessile avicularium of *Scrupocellaria scruposa*; and C, Pedunculate avicularium. *b*, Beak; *c*, Chamber of the avicularium; *m*, Muscles; *p*, Peduncle. All the figures are enlarged. (After Hincks and Busk.)

depressions on the surface of the cells. In some instances it can be shown, as, for example, in the recent *Retepora*, that the avicularia are really attached to thickened tubes which pass deep into the substance of the polyzoary, and which can therefore be readily recognised in thin sections (fig. 455, A). This observation is of considerable interest as affording a possible explanation of certain thickened tubular structures which are found in some of the Palæozoic *Polyzoa*. The structures in question have the form of tubes with thickened fibrous walls, embedded in the solid tissue of the polyzoary; and when cut across transversely in thin sections (fig. 455, B and C), they exhibit a minute central clear spot surrounded

by a dark margin. They were first recognised by Mr John Young as occurring in some of the *Fenestellidæ* (fig. 467), and they were compared by this observer with the "acanthopores" of the Monticuliporoids. They occur, however, in other Palæozoic *Polyzoa* beside the Lace-corals (as in *Coscinium* and in species of *Rhombopora*), and it may be conjectured that they are of the same nature as the small thick-walled tubes in the polyzoary of the existing *Retepora* (fig. 455, A), in which they support the avicularia.

In many of the *Polyzoa* the cells are furnished with special dilatations, which serve as marsupial pouches for the ova, and which are known as the "ovicells" or "oœcia." In general, these peculiar brood-pouches have the form of helmet-shaped or sac-like chambers springing from the anterior end of the cell (fig. 451, B, *o*), with

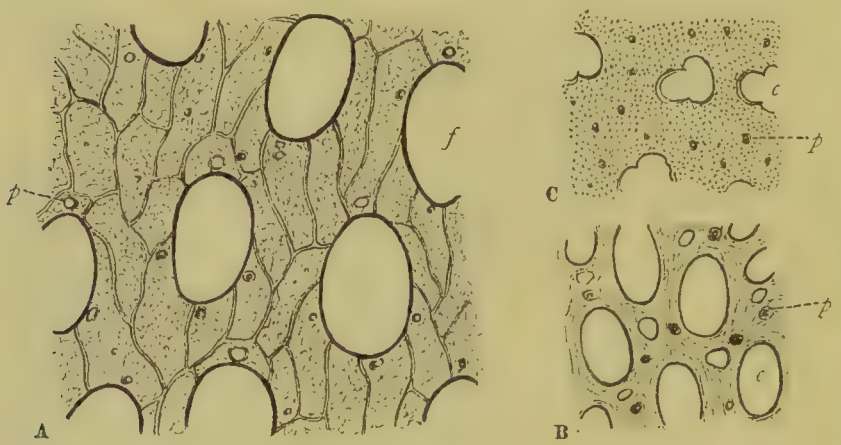


Fig. 455.—A, Tangential section of a recent species of *Retepora*, taken parallel to the non-poriferous surface of the polyzoary, enlarged, showing the thickened tubes (*p*) to which the avicularia were attached; B, Tangential section of *Rhombopora* (*Ceriopora*) *Hamiltonensis*, from the Devonian rocks of Canada, enlarged, showing thickened tubes (*p*); C, Tangential section of *Coscinium* (*Coscinotrypa*) *cribriforme*, from the Devonian rocks of Canada, enlarged, showing similar thickened tubes (*p*). *c*, Cavity of a cell; *f*, One of the "fenestræ" of *Retepora*. (Original.)

the cavity of which they communicate by an aperture or fissure in their hinder wall. Ovicells are not only found in the recent *Cheilostomata* generally, but occur also in numerous Secondary and Tertiary types. Mr Ulrich has likewise recognised in certain of the Fenestellids structures which appear to be of the nature of ovicells; but with this exception no traces of these organs have hitherto been detected in the Palæozoic *Polyzoa*.

In various of the Cyclostomatous *Polyzoa* the mouths of a greater or less number of the cells may be closed by a calcareous membrane, covering parts of the surface more or less completely. In other cases (as in *Mesenteripora* and sometimes in the Palæozoic *Polypora*), individual cells may have their mouths closed by a calcareous lid, which may exhibit a minute central perforation, or, in

other cases, a projecting tubule. Mr Waters has further shown that in the *Cyclostomata* it is not uncommon for a calcareous plate to be developed at the point where the zoœcial tube rises free from the polyzoarium; while in other cases, two of these "closing-plates" are developed close together. Probably of a similar nature to the "closing-plates" just mentioned are the transverse calcareous partitions which are developed in the tubes of various Cyclostomatous *Polyzoa*, both recent and fossil, and which have been spoken of as "tabulæ," from their similarity to the structures known by this name in many Corals. These so-called "tabulæ" differ from the "closing-plates" described by Mr Waters in being developed in the deeper



Fig. 456.—Minute structure of the recent *Heteropora pelliculata*, Waters (= *H. neozelanica*, Busk). A, Tangential section of the polyzoary, enlarged about fifty times, showing the proper zoœcia (*a*, *a*) and interstitial tubes (*b*) connected by numerous minute tubules (*c*). The cells are furnished with numerous radiating spines or "rays." B, Part of a longitudinal section, enlarged about twenty times, showing connecting-pores, "rays," and delicate transverse partitions or "tabulæ." (Original.)

as well as in the more superficial portions of the colony, and they are sometimes present in considerable numbers. They occur in various genera, as, for example, in *Heteropora* (fig. 456, B), *Alveolaria*, *Fascicularia*, *Lichenopora*, &c.; and they are probably connected with the periodic death and renovation of the polypides which is known to occur in many recent *Polyzoa*.

In certain of the *Polyzoa*, finally, the cells are furnished with delicate, radially disposed spines, which present a superficial resemblance to the "septa" of such corals as *Favosites* and certain of the *Heliolitidæ*, and which may be spoken of as "rays." These curious structures (fig. 456, A) have the form of minute calcareous

spines which are directed into the interior of the cell-cavity, their free ends being sometimes globular or button-like. They have been recognised by the present writer in the recent *Heteropora pelliculata* and in some species of *Lichenopora* (*Discoporella*); while Mr Waters has detected them in *Entalophora intricaria*, and in species of *Tubulipora* and *Lichenopora*; and apparently identical structures have been shown by Mr John Young to exist in certain of the *Fenestellidæ*. So far as known, these "rays" are confined to certain of the Cyclostomatous *Polyzoa*, and their precise morphological significance has not as yet been determined. According to a curious observation of Mr Waters, the zoœcia of *Lichenopora grignonensis* not only possess "rays" in their interior, but are also furnished with similar spines projecting from portions of the *external* surface.

As regards their *classification*, the *Polyzoa* may be divided into the three primary sections of the *Ectoprocta*, *Entoprocta*, and *Aspidophora*, of which the last two require no further characterisation here, as they are not known to possess any fossil representatives. The division of the *Ectoprocta*, on the other hand, includes the great majority of the living *Polyzoa* and the whole of the fossil forms, though the essential feature of the division is the position of the anal opening outside the tentacular circle,—a character which, necessarily, can only be positively determined in living examples. The *Ectoprocta* may be divided into the two orders of the *Phylactolæmata* and *Gymnolæmata*, the former characterised by the almost universal feature that the tentacular crown is horse-shoe-shaped, and by the possession of a peculiar valve-like organ ("epistome") arching over the mouth; while the tentacular crown in the latter is circular and there is no epistome. The Phylactolæmatous *Polyzoa* are confined to fresh waters, and they need not be considered here further, as no fossil examples of the order have ever been detected. The order of the *Gymnolæmata*, on the other hand, is of great importance, as comprising the vast majority of the existing marine *Polyzoa* and all the known fossil forms. The order may be divided into the three sub-orders of the *Cyclostomata*, the *Cheilostomata*, and the *Ctenostomata*, the first two characterised by the form of the cell and the absence or presence of an opercular valve to the cell-aperture, while the last is distinguished by the fact that the cells arise from a common tube, their mouths being terminal and furnished with a setose fringe for their closure.

As regards their *distribution in time*, the earliest known forms of the *Polyzoa* are found in the Ordovician rocks, and all the later Palæozoic formations abound in Polyzoan remains. Even in the Ordovician rocks the *Gymnolæmata* are represented by numerous and very widely different types, and the primitive forms of the class must have existed in Cambrian or in even earlier periods. The

Palæozoic *Polyzoa* appear to be for the most part referable to the Cyclostomatous division of the *Gymnolæmata*, and no unequivocal examples of the *Cheilostomata* have been hitherto recognised in any Palæozoic formation. The form described by the present author from the Ordovician rocks as *Hippothoa? inflata* is referable to *Stomatopora* (as this genus is usually understood), and in that case is Cyclostomatous, as also is the *Hippothoa devonica* of Œhlert. It is, however, possible that the Palæozoic genus *Paleschara*, of Hall, is really Cheilostomatous. While the Palæozoic *Polyzoa*, therefore, must in the meanwhile be referred in a general way to the *Cyclostomata*, it has to be borne in mind that many of them exhibit very peculiar characters, and that certain forms are apparently transitional between the *Cyclostomata* and the *Cheilostomata*. It is, in fact, not improbable that fuller investigation of the characters and structure of the Palæozoic *Polyzoa* will render it necessary to recast the classification of the *Gymnolæmata;* and steps in this direction have already been taken by Mr Ulrich. It does not seem possible, however, to accomplish this satisfactorily at present, since we are not only still imperfectly acquainted with the minute structure of many Palæozoic *Polyzoa*, but there are various Palæozoic organisms, the precise place of which in the zoological series has not yet been ascertained with certainty. This is notably the case with the great Palæozoic group of the Monticuliporoids, which, for reasons previously given (see p. 352), have been here placed provisionally beside the Cœlenterates, while they are regarded by Lindström, Ulrich, and other authorities as belonging to the *Polyzoa*. It is also not impossible that we may have in the Palæozoic rocks representatives of other groups of the existing *Polyzoa* than the *Cyclostomata* and *Cheilostomata*. Thus, the singular genus *Ascodictyon*, of the Silurian, Devonian, and Carboniferous rocks, may possibly be, as suggested by Mr Vine, a representative of the *Ctenostomata*, or may even be referable to the section of the Entoproctous *Polyzoa*.

The earlier Secondary deposits (Trias and Lias) have hitherto yielded very few remains of *Polyzoa;* but numerous forms of this class are known in the later Jurassic and in the Cretaceous rocks, the Upper Chalk, in particular, being extraordinarily rich in the remains of these organisms. In the earlier part of the Secondary period, by far the larger number of the known *Polyzoa* are still referable to the *Cyclostomata*, but in the later portion of the Cretaceous period the *Cheilostomata* are likewise largely represented. In the Tertiary rocks, again, not only are the remains of *Polyzoa* abundant, but the majority of the forms represented are now referable to the *Cheilostomata*, the Cyclostomatous types undergoing a decided reduction. All the great divisions of the Tertiary rocks have yielded

more or less numerous *Polyzoa* (fig. 457); but the Upper Oligocene of Germany, the Miocene deposits of France, Austria, Switzerland,

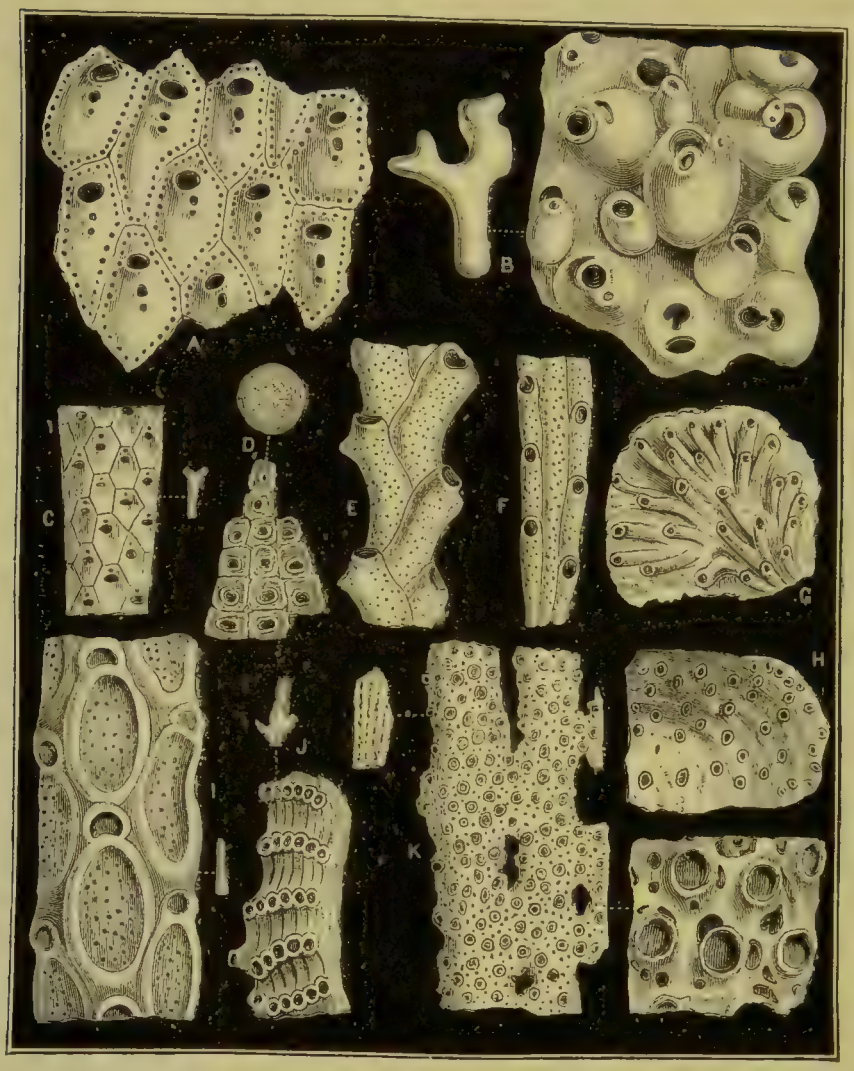


Fig. 457.—Types of Tertiary Polyzoa. A, A few cells of *Microporella violacea* (Pliocene and Recent), magnified; B, *Cellepora coronopus*, of the natural size, and a portion of the surface enlarged (Pliocene); C, A small piece of *Cellaria* (*Salicornaria*) *crassa*, of the natural size and enlarged (Pliocene); D, *Lunulites quadrata*, of the natural size, and a small portion of the upper surface enlarged (Tertiary); E, A fragment of *Scrupocellaria elliptica*, viewed from behind, enlarged (Tertiary); F, A small piece of *Crisia denticulata* (Tertiary), enlarged; G, A fragment of *Tubulipora flabellaris* (Tertiary), enlarged; H, A fragment of *Diastopora simplex*, enlarged (Tertiary); I, A piece of *Vincularia Haidingeri*, natural size and enlarged (Tertiary); J, *Idmonea fenestrata*, natural size and enlarged (Tertiary); K, *Hornera reteporacea*, natural size and enlarged (Tertiary). (After Busk and Reuss.)

and Italy, and the Pliocene beds ("Coralline Crag") of Britain, have proved particularly rich in the remains of these organisms.

In the following general account of the characters and chief groups

of the fossil *Polyzoa*, no attempt will be made to give a complete review of the different families. Not only is the classification of the fossil *Polyzoa* in an admittedly unsatisfactory state, but the characters of many of the fossil types cannot be rendered intelligible without the free use of illustrations, even where these are thoroughly understood; while there are many types the structure of which is at present only imperfectly known. Nothing further will therefore be attempted here than to shortly characterise some of the more important and more widely distributed groups, and to indicate the chief forms of these and their general geological range; all the fossil types here referred to being provisionally distributed between the *Cyclostomata* and the *Cheilostomata*.

Sub-Order I. Cyclostomata.

This sub-order, as has been previously seen, includes Gymnolæmatous *Polyzoa*, in which the cells are more or less tubular, the cell-aperture being terminal, usually of the same diameter as the tube itself, and not provided with a movable operculum for its closure. In a large number of the *Cyclostomata*, the tubes (fig. 451, A) are free for a larger or smaller portion of their length, so that the surface of the colony is partly formed by the lateral walls of the zoœcia; while in other types (fig. 456, B) the tubes are in contact throughout their entire length, the cells thus opening at right angles to the axis or surface of the colony, and the whole exterior being thus occupied by the cell-apertures. This difference probably expresses a genuine structural distinction, and upon it Mr Waters has proposed to divide the *Cyclostomata* into the two divisions of the *Parallelata*, with partially free tubes, and the *Rectangulata*, with the tubes in contact throughout.

In most of the *Cyclostomata* the calcareous walls of the cells are pierced by smaller or larger pores, but in some cases the walls appear to be completely imperforate. In many forms all the cells are similar to one another, but in others (*e.g.*, in *Heteropora*) the colony consists of two sets of tubes, which are similar in internal structure, but differ in point of size. In other forms referred to this sub-order an interstitial vesicular tissue appears to be developed between the proper zoœcia. "Ovicells" are developed in certain of the *Cyclostomata*, but they have not been observed in others, and they do not play such a conspicuous part as they do in the *Cheilostomata*. In various forms of the *Cyclostomata*, finally, radiating spines or "rays" are developed in the cells, while the structures previously alluded to as "closing-plates" and "tabulæ" are not uncommonly present.

The *Cyclostomata* are the most ancient group of the *Polyzoa*,

being represented by numerous forms in all the great geological formations from the Ordovician onwards. With a few possible exceptions, as already noted, the whole of the Palæozoic *Polyzoa* may be provisionally referred to the *Cyclostomata;* but while some of even the oldest forms belong to quite normal groups of this suborder, others differ widely from the regular type, and will probably be ultimately referred elsewhere. Leaving these last out of consideration, the *Cyclostomata* may be said to attain their maximum development in the Jurassic and Cretaceous rocks, a decided diminution in their numbers taking place in the Tertiary period.

Taking the normal groups of the *Cyclostomata* first, and leaving out of sight certain comparatively unimportant types, the family of the *Crisiidæ* comprises a small number of dendroid forms, in which the polyzoary consists of calcareous segments united by corneous joints, the tubular zoœcia being either uniserial or biserial (fig. 457, F). The type of this family is *Crisia* itself, which is represented by numerous Tertiary and recent species.

The family of the *Tubuliporidæ* (*Stomatoporidæ*) comprises forms in which the polyzoary is usually creeping and wholly adherent by its under surface, or partially free and erect. The tubular zoœcia may be disposed uniserially, or biserially, or irregularly grouped, their upper ends being more or less extensively free. The ovicells are represented by "an inflation of the zoarium at certain points, or a modified cell" (Hincks).

In the genus *Tubulipora* itself the colony is more or less extensively attached by its base (fig. 457, G), and the tubular zoœcia are free for a great part of their length and radiate from an excentric point. The species of this genus range from the Cretaceous rocks to the present day. The forms included under the head of *Stomatopora* (*Alecto*) differ considerably in their characters. In one group of forms comprised under this generic name the colony is completely adherent to foreign bodies, and the tubular cells are more or less extensively immersed, being free close to their mouths only; so that a more or less strap-shaped, often branched frond is produced (figs. 451, A, and 459, B and C), the walls of the zoœcia being at the same time porous, and usually either biserial or multiserial. In some forms (*Proboscina*), the polyzoary has the above characters, but is partially free and erect. Forms of the type here indicated are found in rocks as ancient as the Ordovician, while numerous species still exist. On the other hand, there have been included in *Stomatopora* various forms in which the polyzoary consists of a creeping adherent network, formed of uniserial or sometimes alternatingly biserial cells, which spring directly from each other, each new tube being produced from the anterior end of the lower surface of the preceding cell (figs. 458 and 459, D). The tubes are thick-walled and destitute of pores, and the colony often closely resembles an *Aulopora* in form. Indeed, the only essential distinction between such colonies and *Aulopora* is to be found in the fact, that in the typical species of the latter there appears to be a creeping basal network from which the tubes are sent up at intervals, instead of springing directly from one another; but it is not clear

how far even this distinction can be relied upon. Forms of this second type occur from the Ordovician rocks onwards. It would seem that these two groups of *Stomatoporæ* should be generically separated from one another, as the differences above pointed out are of substantial import-



Fig. 458. — A specimen of *Stomatopora dichotoma*, from the Great Oolite, of the natural size. (After Zittel.)



Fig. 459.—A, A fragment of shell with *Stomatopora auloporoides* and *S. inflata* growing on it, of the natural size, from the Cincinnati group (Ordovician) of America; B, *Stomatopora auloporoides*, enlarged; C, Part of the same, enlarged still further; D, *Stomatopora inflata*, enlarged; E, Fragment of *Hederella Canadensis*, from the Devonian rocks of Canada, of the natural size and enlarged. (Original.)

ance. It would also seem certain that the Silurian and Devonian genera *Reptaria* and *Hederella* (fig. 459, E), sometimes placed among the Corals, should be referred to this family. In these doubtfully distinct genera the colony is branched and adherent to foreign bodies by its lower surface, the branches consisting of long, narrow tubular cells, which spring in an alternating manner from one another, each branch being thus biserial.

Allied to the preceding is the family of the *Diastoporidæ*, in which the polyzoary is usually encrusting and discoid or fan-shaped, though sometimes foliaceous and erect. The tubular cells are in



Fig. 460.—*Mesenteripora* (*Bidiastopora*) *cervicornis*, natural size and enlarged. Jurassic.

great part immersed, their ends only being usually free, and the peripheral part of the colony may be formed of small, angular "germinal" cells. The species of *Diastopora*, in a restricted sense, form small crusts upon foreign bodies, and range from the Jurassic to the present day. Allied types appear in the Silurian rocks, and

have been referred by Mr Vine to the genus *Diastoporella*. The foliaceous and erect forms of *Diastopora* are sometimes included under the separate generic name of *Mesenteripora*, or, if consisting of two layers of cells placed back to back, of *Bidiastopora* (fig. 460).

Berenicea comprises forms which hardly appear to be separable from *Diastopora*; but the typical forms placed under this head consist of crusts of superimposed cells. The genus has been quoted from the Ordovician rocks, and there are numerous undoubted Secondary, Tertiary, and Recent species.

Also related to the *Tubuliporidæ* is the family of the *Entalophoridæ*, in which the polyzoary is erect and free, rising from an expanded adherent base, and formed of long tubular cells which usually open all round the stems. The genus *Entalophora* (*Pustulopora*) itself ranges from the Jurassic to the present day, and has the cells open-



Fig. 461.—*Entalophora* (*Pustulopora*) *cellarioides*, of the natural size and enlarged. Jurassic.

ing irregularly on all sides of the branches. The name of *Spiropora* is usually given to forms essentially similar to the preceding, but having the cells so disposed that the cell-mouths form simple circles or spirals round the stems. Species of *Spiropora* appear as early as the Silurian period, and numerous Secondary and Tertiary types are known, while the genus still survives.

In the family of the *Idmoneidæ*, the polyzoary is erect, and almost always more or less branched, the branches being usually round, and sometimes anastomosing with one another. The tubular cells open on one side only of the polyzoary. In the genus *Idmonea* itself (fig. 457, J) the cells are disposed in transverse or oblique rows on each side of the front faces of the branches, which are divided mesially by an angulation or longitudinal keel. The genus ranges from the Chalk to the present day. In the genus *Hornera* (fig. 457, K), again, the polyzoary is branched and sometimes reticulated, the cells opening on one side of the branches only, their mouths being commonly placed in somewhat rhomboidal spaces marked out by wavy anastomosing ridges. Interstitial pores occur between

the cell-mouths, and may be developed on the non-celluliferous dorsal surface. The earliest undoubted species of *Hornera* occur in the Cretaceous rocks, and there are numerous Tertiary and recent types.

The family of the *Lichenoporidæ* comprises discoid polyzoaria, which sometimes in process of growth become confluent, or may even become massive, the colony being fixed by a broad adherent base or by a narrow peduncle. The zoœcia are tubular and erect, and are in complete contact throughout, or are free towards their extremities. The walls of the zoœcia may be porous or imperforate, and the proper zoœcia may be separated by intermediate cancellated or porous spaces.

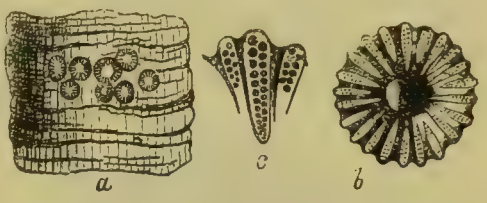


Fig. 462.—*Botryllopora socialis*, from the Devonian rocks of Canada. *a*, A small colony attached to a coral, of the natural size; *b*, A single disc of the same, enlarged; *c*, A small portion of the same, enlarged still further. (Original.)

The most ancient type of the *Lichenoporidæ* appears to be the genus *Botryllopora* of the Devonian rocks (Hamilton formation) of Canada and the United States. In this genus (fig. 462) the polyzoary consists of separate or confluent discs, which are attached by the whole of the under surface to foreign bodies. Each disc shows a series of elevated ridges or ribs, which radiate from a central area and are separated by intervening furrows. The ribs carry the apertures of the tubular zoœcia, and the spaces between them appear, in well-preserved specimens, to be minutely porous. The genus *Lichenopora* (*Discoporella*) comprises forms in which the polyzoary has the form of a simple disc or of numerous confluent discs, each disc being composed of tubular cells, which are arranged in lines radiating from a central space, and separated by intervening intervals. The zoœcia are free towards their mouths, and project above the general surface; and the spaces between them, as well as the central area, are occupied by smaller interstitial tubes or "cancelli." In some forms, both the proper zoœcia and the "cancelli" are provided with delicate capitate "rays." In many structural features *Lichenopora* closely approaches *Heteropora*, but the zoœcia of the latter are in contact throughout, and are not free towards their extremities. The forms with confluent discs are sometimes separated to constitute the separate genus *Radiopora*. The earliest types of *Lichenopora* (if considered as embracing *Radiopora*) appear in the Trias; while the genus has Jurassic, Cretaceous, and Tertiary representatives, and still survives at the present day. In the genus *Domopora* (*Defrancia*) the polyzoary is discoidal or massive, simple or lobed, attached by the whole base or by a stalk, or sometimes free. The zoœcia are "disposed in radiating lines, consisting of one or more series, on the free extremity of the stem or lobes" (Hincks), and their mouths do not project above the general surface. The walls of the zoœcia are penetrated by numerous delicate tubuli. This genus should perhaps be removed to the family of the *Heteroporidæ*. The species of *Domopora* appear first in the Jurassic, and are abundant in the Chalk, while Tertiary and living forms are also known.

The singular genus *Alveolaria* (fig. 463) may likewise be associated with the *Lichenoporidæ*—the only described species being the *A. semiovata* of the Red Crag (Pliocene) of Britain. In this remarkable form the polyzoary is massive and globose, consisting of numerous mushroom-shaped discs or cups, which are arranged in radiating and diverging lines, the cups of each vertical series springing directly from one another (fig. 463, C); and the different groups being so disposed that they form a series of thick concentric layers. Each concentric stratum is thus made up of a number of discs which are firmly united by their edges, but are free towards their bases; and each disc is enclosed in a strong calcareous membrane, the upper surface alone being free, and ex-

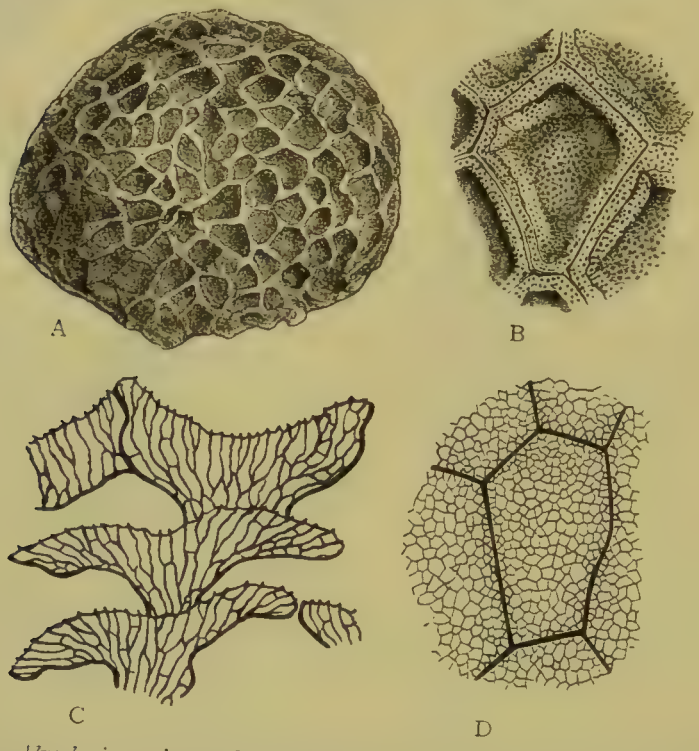


Fig. 463.—*Alveolaria semiovata*, from the Red Crag (Pliocene) of Britain. A, A specimen of the natural size; B, A portion of the surface enlarged; C, Part of a vertical section enlarged; D, Part of a tangential section enlarged. (Original.)

hibiting the apertures of the cells. The laterally-united discs are polygonal, and the surface (fig. 463, A and B) thus shows a number of polygonal cups bounded by strongly elevated ridges, each of which, in turn, exhibits a raised median line corresponding with the free edge of the epithecal membrane. For the same reason, tangential sections (fig. 463, D) show that the tubes are divided into polygonal groups, each of which is bounded by a strong external wall. The tubes themselves are in close contact throughout, their mouths not projecting above the general surface. The walls of the tubes are apparently completely imperforate; but "closing-plates" or "tabulæ" are often developed.

The family of the *Frondiporidæ* (*Theonoidæ*) includes forms in which the polyzoary is composed of long contiguous tubes, the

mouths of which are commonly disposed in groups of different size and form, separated by porous or imperforate interspaces. The genera *Frondipora* and *Fasciculipora* (*Fungella*) are both represented by species which range from the Chalk to the present day, and there are several other genera which are found in the Cretaceous or Tertiary rocks. Of the Tertiary forms the most interesting is the genus *Fascicularia* (*Mæandropora*), which is exceedingly abundant in the Red Crag (Pliocene) of Britain. In this genus (fig. 464) the

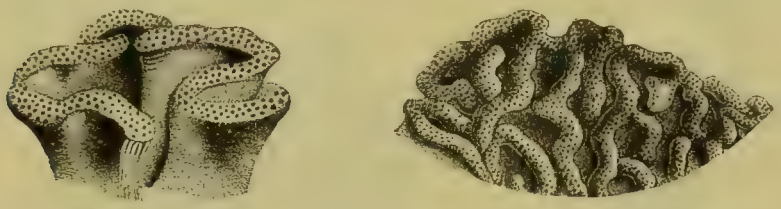


Fig. 464.—*Fascicularia* (*Mæandropora*) *cerebriformis*. Tertiary.

polyzoary is more or less massive, generally globose, and often of large size, composed of long calcareous tubes arranged in bundles, the tubes of each bundle being in contact, and the bundles being enclosed laterally in a calcareous membrane. The bundles diverge from the base of the colony, and may be connected by horizontal and concentric plates, or may be confluent by their sides and thus give rise to vertical convoluted laminæ. The tubes are destitute of "rays," but exhibit horizontal "tabulæ," and have minutely porous walls. In the common *Fascicularia aurantium* of the Red Crag the tubes open on the surface in sinuous anastomosing ridges, while in the allied *F. tubipora*, of the same formation, they open on rounded eminences.

The family of the *Heteroporidæ* is in some important respects related to that of the *Lichenoporidæ*, and comprises the genera *Heteropora* and *Heteroporella*. The polyzoary in this family may be erect and branched, or may be encrusting; and is composed of tubular zoœcia which are interspersed among similarly tubular but somewhat smaller "cancelli," all the tubes being in close contact throughout, and the mouths of the zoœcia not projecting above the general surface. The walls of the zoœcia and interstitial tubes or cancelli are penetrated by minute tubules, which place contiguous cells in communication (fig. 456); and in some species at any rate, delicate radiating spines ("rays") are developed. There is also generally a larger or smaller number of "closing-plates" or "tabulæ," which are principally developed in the deeper parts of the colony. In the genus *Heteropora* itself, the colony is erect and branched, the tubes being vertical in the centre of the branches, but bending out-

wards to reach the surface, their walls being considerably thickened in the outer part of their course (fig. 456, B). The earliest forms of *Heteropora* appear in the Jurassic rocks, and the genus has survived to the present day. The forms included by Busk in *Heteroporella* are Cretaceous and Tertiary, and the polyzoary is said to differ from that of *Heteropora* in being discoid and encrusting.

The family of the *Fenestellidæ* or "Lace-corals" constitutes one of the largest and most important groups of the Palæozoic *Polyzoa*, no Secondary or Tertiary types belonging to this family having been

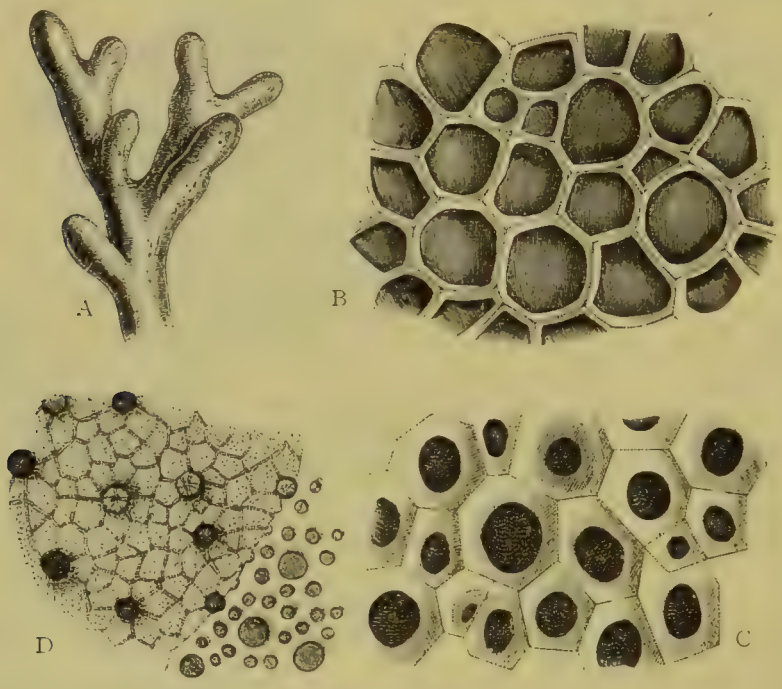


Fig. 465.—*Heteropora pelliculata*, Waters (=*H. neozelanica*, Busk), a recent species of *Heteropora*. A, A fragment of the polyzoary of the natural size; B and C, Portions of the surface of different specimens, enlarged, showing the apertures of the zoœcia and cancelli; D, A portion of the surface of another specimen in which the mouths of the cancelli and some of the zoœcia are in places covered by a calcareous pellicle, enlarged. (After Busk, Waters, and the Author.)

hitherto recognised. In all the members of this family the polyzoary is reticulated, generally fan-shaped or funnel-shaped, and composed of rigid, calcareous, parallel or slightly diverging branches, which may be united by cross-bars or "dissepiments," or may be sinuous and may unite regularly by anastomosis; the frond coming in both cases to be perforated by symmetrically disposed, sub-quadrate or oval spaces or "fenestrules" (figs. 466 and 467). The zoœcia have the form of short, utricular tubes, arranged in two or more series on one side only of the branches, the reverse side being non-poriferous, and being commonly finely striated. When true "dissepiments" are present, they are non-poriferous. The mouths of the zoœcia are

more or less circular, and are often provided with a projecting lip or "peristome."

The minute structure of the polyzoary in the *Fenestellidæ* appears to be very uniform. The cells themselves are formed of a layer of

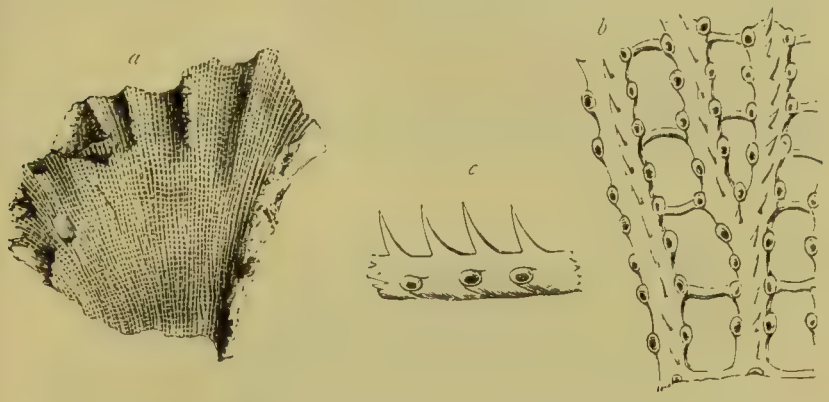


Fig. 466.—*Fenestella Lyelli*. *a*, Natural size; *b*, Portion enlarged; *c*, Cells and spines in profile. From the Carboniferous rocks of Canada. (After Dawson.)

perfectly homogeneous compact calcite, which is strengthened by a basal striated membrane; while the reverse or non-poriferous side of the polyzoary is composed of a thick stratum of calcareous tissue

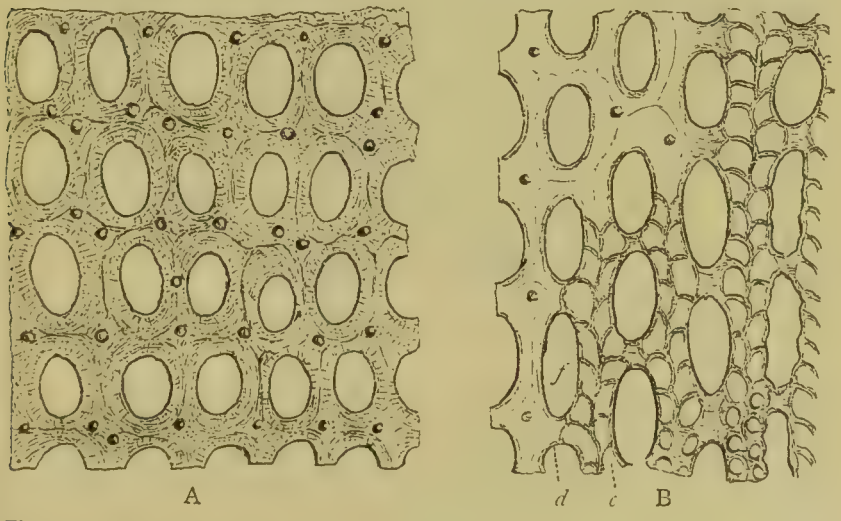


Fig. 467.—Minute structure of *Fenestella tuberculocarinata*, from the Carboniferous rocks of Scotland. A, Section taken parallel to the non-poriferous surface, showing thickened tubes (for the support of "avicularia"?), enlarged. B, Section parallel to the celluliferous surface of the polyzoary, showing the biserial cells (*c*): *d*, Dissepiments; *f*, Fenestrules. (Original.)

traversed by exceedingly minute tubuli, the direction of which is perpendicular to the surface, and which communicate to thin sections of this region of the skeleton an exceedingly characteristic

appearance (fig. 453). In some cases, as previously noted, the dorsal or non-poriferous side is traversed by remote, thick-walled, and comparatively large tubes (fig. 467, A), which may project above the surface of the polyzoary, and which may, perhaps, have served for the support of processes similar to the "avicularia" of the recent *Polyzoa*. In certain forms of the *Fenestellidæ* (species of *Fenestella* and *Polypora*), it has been shown by Mr John Young that the polyzoary was furnished on its margins or external surface with certain remarkable appendages, which were originally described by Professor Martin Duncan and Mr Jenkins under the name of *Palæocoryne*,

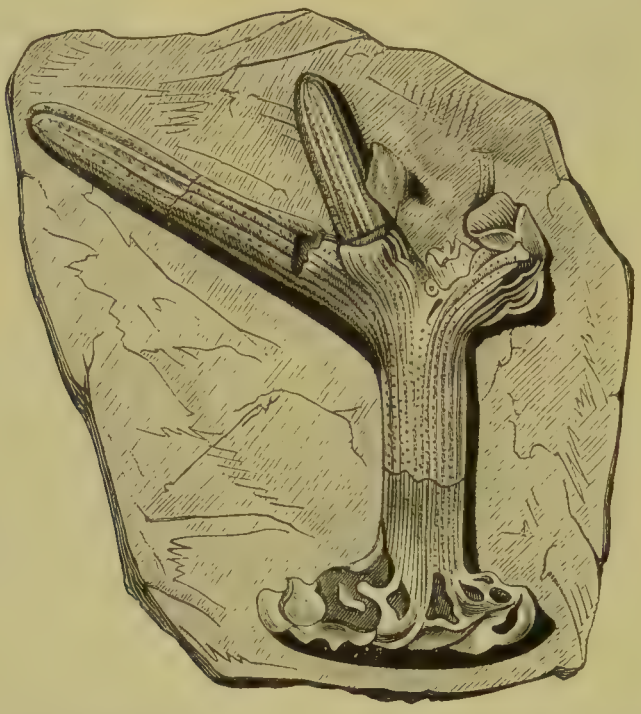


Fig. 468.—Branched appendage of a Fenestellid (the *Palæocoryne radiatum* of Duncan and Jenkins), enlarged fifteen diameters. (After Martin Duncan and H. M. Jenkins.)

and which were regarded by these observers as belonging to the *Hydrozoa*. The appendages in question (fig. 468) are of small size, and have the form of short, robust, calcareous stems, which spring from an expanded base, and are usually marked with longitudinal flutings or superficial granulations, while the free extremity generally terminates in a whorl of similarly fluted and ornamented cylindrical processes. In some cases, as shown by Mr John Young, the terminal processes may be curved or hooked, or they may be even united by lateral cross-bars. The observations of Mr Young prove conclusively that the structures described under the name of *Palæocoryne* truly form parts of the Polyzoan to which they are

attached, since thin sections prove the absolute continuity of the substance of the two; while the processes themselves consist, as does the polyzoary from which they spring, of an external finely-tubulated layer and an internal homogeneous stratum. The nature and use of these singular appendages cannot at present be more than guessed at.

As regards the chief types of the *Fenestellidæ*, the genus *Fenestella* itself ranges from the Silurian to the Permian inclusive, and comprises a large number of species, the greater part of which belong to the Devonian and Carboniferous rocks. In this genus (figs. 467, 468, and 469, C and

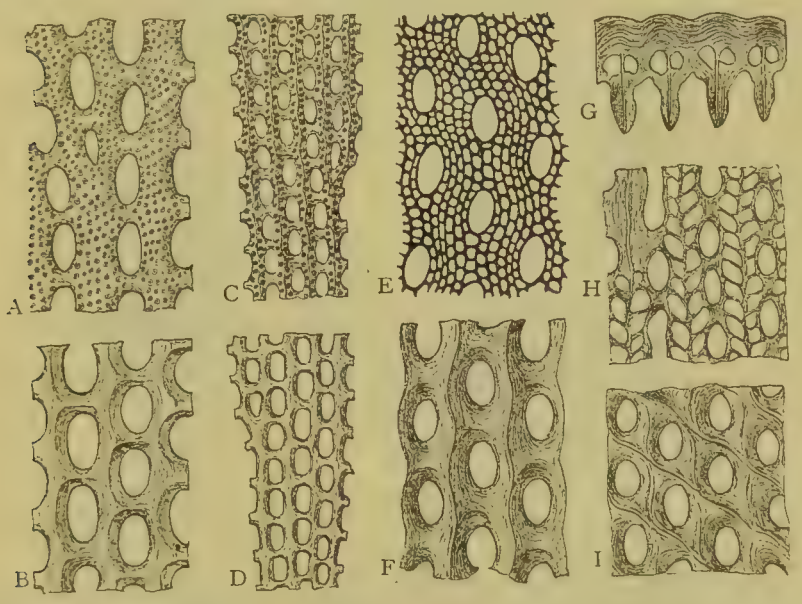


Fig. 469.—A, Poriferous side of *Polypora rigida* (Devonian); B, Non-poriferous side of the same; C and D, Poriferous and non-poriferous sides of *Fenestella biseriata* (Devonian); E, Section of *Phyllopora* sp. (Devonian), showing the anastomosing branches and the form and arrangement of the cells; F, Non-poriferous side of the same; G, Transverse and vertical section of *Carinopora Hindei* (Devonian), showing the greatly developed keels, with the biserial cells at their bases; H, Section of the same parallel with the poriferous face; I, Part of the non-poriferous side of the same. All the figures are enlarged. (Figs, A—D are after Hall; E—I are original.)

D), the polyzoary is fan-shaped or infundibuliform, the cells being developed on one side only, this being generally, if not always, the *inner* side of the colony. The branches are straight, and are connected at short intervals by regularly placed, non-poriferous cross-bars, or "dissepiments." The zoœcia are always biserial, the two rows of each branch being separated by a median ridge or keel. In its general structure the Devonian genus *Carinopora* (fig. 469, G—I) resembles *Fenestella*, the polyzoary being funnel-shaped, with the cells opening on the *inside*, and each branch having a double row of cells separated by a median keel. In this genus, however, the keels on the branches are enormously developed, and the external aspect of the polyzoary resembles that of *Phyllopora*. The genus *Semicoscinium*, also from the Devonian rocks, is considered by Ulrich as identical with *Carinopora*, but in this case the zoœcia open

on the *outside* of the funnel-shaped polyzoary. The remarkable Devonian genus *Unitrypa*, again, resembles the two preceding types in general structure; but the projecting keels which separate the two rows of cells on each branch are widened at their summits, and are connected with one another by thin lateral processes placed at variable distances. In the Carboniferous genus *Ptilopora* (fig. 470) are included forms which agree in essential structure with *Fenestella*, but differ in the feather-like form of the frond, the polyzoary having a central stem which gives off lateral branches in a pinnate manner, these latter being connected by dissepiments separated by oval fenestrules. The genus *Archimedes* (*Archimedipora*) is another remarkable Carboniferous type, in which the general structure is like that of *Fenestella*, but the reticulate polyzoary is wound in an obliquely spiral manner round a central screw-like axis (fig. 471, *c*). The genus *Helicopora* has a similarly spiral zoarium, but there

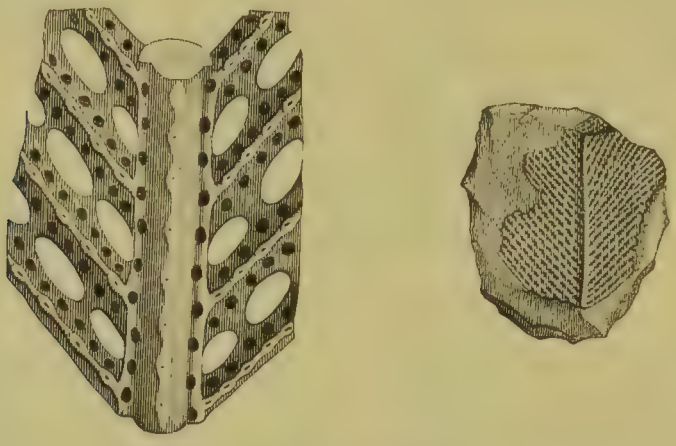


Fig. 470.—*Ptilopora pluma*; the right-hand figure of the natural size, the left-hand figure enlarged. Carboniferous.

is no central axis developed. *Lyropora*, from the Carboniferous rocks of North America, resembles *Fenestella* in general features; but the net-like polyzoary is bounded by solid lateral supports, which spring, like the two branches of the letter U, from a small base of attachment. Lastly, the genus *Fenestralia*, likewise from the Carboniferous rocks of North America, differs from *Fenestella* principally in the fact that there are *two* rows of cells on each side of the median keel in each branch.

The Carboniferous genus *Actinostoma* resembles *Fenestella* in having a fenestrated polyzoary which is poriferous on one side only; but the branches are not keeled, the cell-mouths are furnished with radiating teeth or "rays," and the zoœcia have a second supplementary pore close to the proper aperture. The widely distributed genus *Polypora* (fig. 469, A and B, and fig. 471, *a*) agrees with *Fenestella* in general structure, but the branches are not keeled, and there are from three to six rows of cells to each branch. As in *Fenestella*, however, the branches are connected by solid, non-poriferous "dissepiments." On the other hand, in the genus *Phyllopora* (the *Retepora* of many authors) the branches which compose the funnel-shaped polyzoary are not joined by dissepiments, but are sinuous, and anastomose with one another at short and regular intervals, so as to give rise to a symmetrically disposed system of "fenestrules" (fig. 469, E and F). The zoœcia are placed on the inner side of the frond,

each branch having from two to five rows of cells. The species of *Phyllopora* range from the Ordovician rocks to the Permian. Lastly, in the Carboniferous genus *Goniocladia* the branches anastomose as in *Phyllopora*, but they are keeled on both sides, and there are three or four rows of cells on each side of the median keel on the poriferous side.

The family of the *Acanthocladidæ* comprises a number of Palæozoic *Polyzoa* which are in many respects allied to the *Fenestellidæ*.

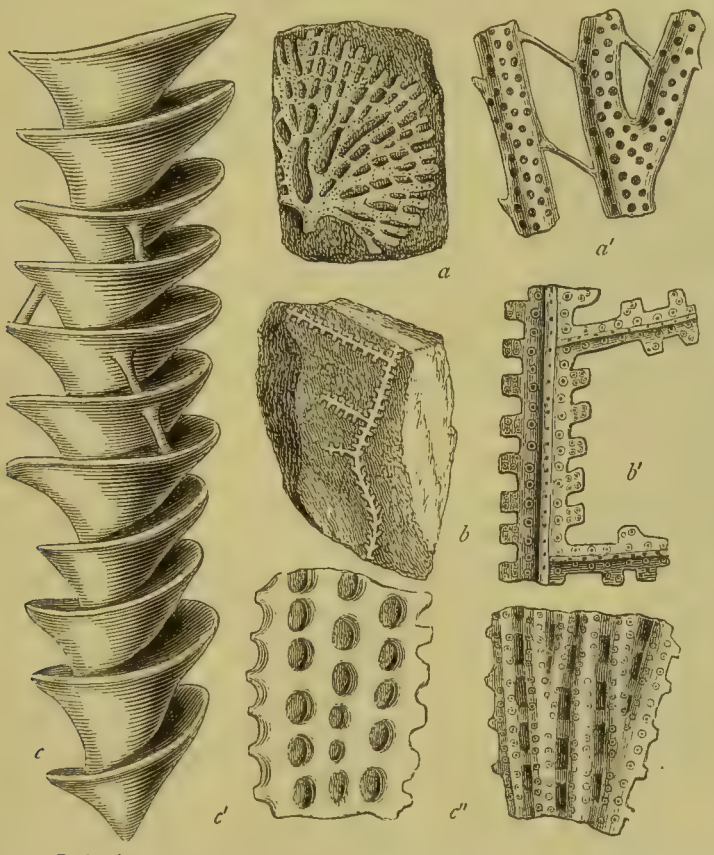


Fig. 471.—Carboniferous *Polyzoa*. *a*, Fragment of *Polypora dendroides*, of the natural size—Ireland; *a'*, Small portion of the same, enlarged to show the cells; *b*, *Pinnatopora* (*Glauconome*) *pulcherrima*, a fragment, of the natural size—Ireland; *b'*, Portion of the same, enlarged; *c*, The central screw-like axis of *Archimedes Wortheni*, of the natural size—Carboniferous, America; *c'*, Portion of the exterior of the frond of the same, enlarged; *c''*, Portion of the interior of the frond of the same, showing the mouths of the cells, enlarged. (After M'Coy and Hall.)

In this family the polyzoary is "poriferous on one side only, dendroid, pinnate, or forming fenestrated expansions, and consisting of strong central stems and numerous smaller lateral branches which proceed from their opposite margins. The lateral branches are free, or may unite (in the fenestrate genera) with those of the adjacent branches. Non-poriferous dissepiments are absent" (Ulrich).

The genus *Acanthocladia* is Carboniferous and Permian, and possesses a polyzoary which is bilaterally branched in a single plane, and which is celluliferous on one side only, the reverse side being solid and striated. The zoœcia are placed on the main stem and branches, and are multiserial. The Carboniferous genus *Pinnatopora* (the *Glauconome* of many authors) resembles the preceding in general form (fig. 471, *b* and *b'*), but the cells are biserial, and the stems have a more or less well-developed keel. The Carboniferous genus *Septopora* resembles *Pinnatopora* generally, but becomes fenestrated by the union of the lateral branches of the polyzoary; while the same thing occurs in the Permian genus *Synocladia*. In this last genus the lateral branches are directed obliquely upwards, and carry two rows of pores each, while the main stems carry from three to five rows of pores separated by a median keel.

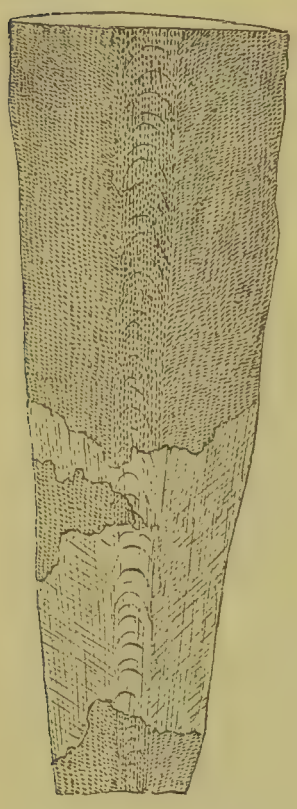


Fig. 472.—A specimen of *Ptilodictya* (*Heterodictya*) *gigantea*, from the Devonian rocks of Canada, of the natural size. The polyzoary is split in half along its median plane, and shows in places portions of the striated calcareous membrane produced by the coalescence of the two layers of cells composing the colony. (Original.)

The families of the *Ptilodictyonidæ*, *Stictoporidæ*, and *Cystodictyonidæ* may be briefly considered together, since they contain Palæozoic *Polyzoa* which are superficially very similar to one another, and which are in many respects really allied, though they differ in the internal structure of the polyzoary. Owing, however, to the fact that various types have been hitherto insufficiently examined by means of microscopic sections, it is not always possible to separate these families accurately, or to refer a particular form to one or other of them. The family of the *Ptilodictyonidæ*, more especially, cannot at present be precisely defined, since the structure of the type-species of the genus *Ptilodictya*—viz., the *P. lanceolata*, Goldf. sp. of the Silurian rocks—has not yet been thoroughly investigated. Judging, however, from external characters alone, it would seem probable that the Devonian Polyzoan described by the writer under the name of *Heterodictya gigantea* is congeneric with *Ptilodictya lanceolata*, as understood by Lonsdale; and we may therefore take the former as exhibiting the essential characters of the genus *Ptilodictya*. The polyzoary in *Ptilodictya* (*Heterodictya*) *gigantea* has the form of a flattened, unbranched, two-edged frond, which reaches several inches in length and an inch or more in width (fig. 472), with a thickness in the centre of about two lines. The polyzoary consists

of two strata of tubular zoœcia, the bases of which unite to form a median calcareous striated layer, along the line of which the frond readily splits. The zoœcia are disposed in parallel longitudinal lines, those of the central rows being themselves longitudinal, while those of the lateral regions of the colony are directed obliquely upwards and outwards, the arrangement of the cells being thus feather-like (fig. 472). The two flattened surfaces of the polyzoary are wholly covered by the minute, oval cell-apertures. As regards the internal structure, the zoœcia have strong, fibrous and imperforate walls, and the cells are traversed by numerous transverse calcareous partitions or "tabulæ," many of which, however, are incomplete, and do not extend the whole way across the tube in

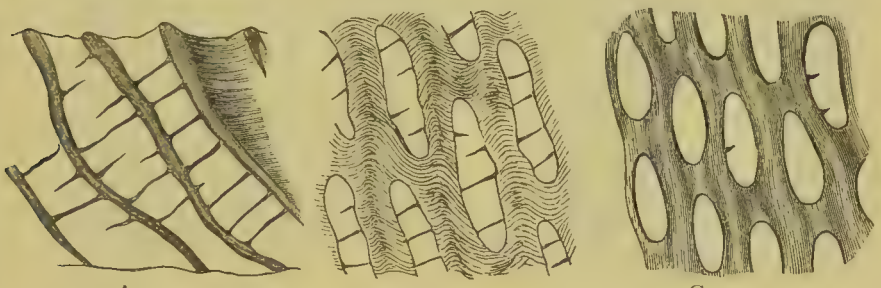


Fig. 473.—Minute structure of *Ptilodictya* (*Heterodictya*) *gigantea*, Nich., from the Corniferous Limestone (Devonian) of Canada. A, Vertical and longitudinal section, showing the well-developed tabulæ; B, Vertical and transverse section, showing the incomplete condition of many of the tabulæ; C, Tangential section. All the figures are enlarged eighteen times. (Original.)

which they occur (fig. 473). The cells run obliquely to the surface, and are in contact throughout, no interstitial tubes or cells being developed.

If the form just described is to be taken as a true *Ptilodictya*, then the essential characters of the genus *Ptilodictya* and of the family *Ptilodictyonidæ* are that the polyzoary is leaf-like, and composed of two layers of tubular zoœcia, which are attached back to back, a spurious mesothecal membrane being formed by the coalescence of their bases; the cells are in contact throughout, no interstitial cells being present; the cell-mouths are simple; and cross-partitions or "tabulæ" are abundantly developed in the tubes. Owing to the uncertainty which at present attaches to the limits of the family *Ptilodictyonidæ*, it is impossible to speak definitely as to the geological range of the family; but *P. lanceolata*, Goldf., is Silurian, and *P.* (*Heterodictya*) *gigantea* is Devonian.

There are various Palæozoic *Polyzoa* that have been commonly placed in the genus *Ptilodictya*, which agree with the preceding in various general characters, but differ in important structural features. Thus,

there are numerous Ordovician and Silurian types, of which we may take *Ptilodictya* (*Stictopora?*) *falciformis* as an example, in which the polyzoary is in the form of an unbranched, or slightly branched, flattened frond (fig. 474, *a*), composed of two layers of cells placed back to back, a more or less recognisable calcareous membrane (the "mesotheca" of Hall) being produced by the coalescence of their bases. In the particular type here selected as an example of this group the polyzoary is usually unbranched, sickle-shaped, and thin-edged, the margins being longitudinally striated, and occasionally perforated by the apertures of minute and imperfect cells. The zoœcia (figs. 474, *c*, and 475, A) are tubular, and in close contact throughout, no interstitial cells being developed;

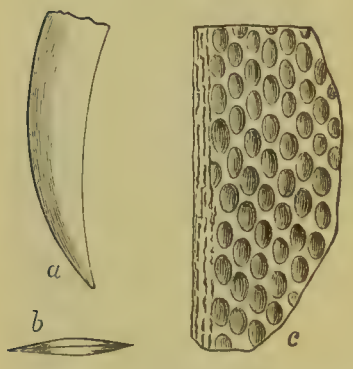


Fig. 474.—*Ptilodictya* (*Stictopora?*) *falciformis*. *a*, Small specimen of the natural size; *b*, Cross-section, showing the shape of the frond; *c*, Portion of the surface, enlarged. Trenton Limestone and Cincinnati Group, America. (Original.)

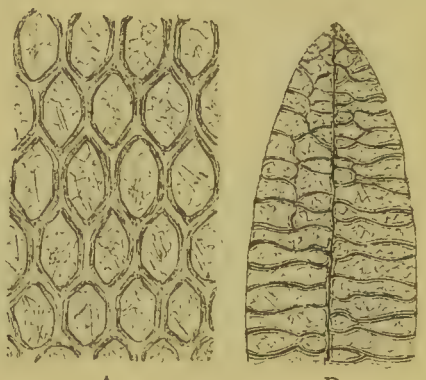


Fig. 475.—Structure of *Ptilodictya* (*Stictopora?*) *falciformis*. A, Tangential section, enlarged, showing the lozenge-shaped tubes; B, Transverse section, enlarged, showing the arrangement of the two layers of cells. (Original.)

and the apertures are oval or lozenge-shaped. The tubes (fig. 475, B) are rectangular to the flat surfaces of the polyzoary, and they do not appear to be traversed by "tabulæ." An essentially similar structure is exhibited by the Silurian Polyzoan described by Hall under the name of *Clathropora frondosa*, which constitutes the type of the genus *Clathropora*. In this case, however, the polyzoary is composite, and is formed by the inosculation of a series of thin leaf-like bilaminar fronds, which anastomose in such a way as to leave regularly placed oval perforations or fenestrules; the minute structure of the tubes resembling that observed in *Ptilodictya falciformis*.

A number of Ordovician, Silurian, and Devonian *Polyzoa*, more or less closely allied in general characters to the types treated of above, have been placed in the family of the *Stictoporidæ*. It does not, however, appear possible at present to give any precise definition of the family, since Hall and Ulrich, who have more especially studied the forms in question, are not agreed as to the limits of the genus *Stictopora*, the type of the whole family. The forms which have been generally included under the name of *Stictopora* are compressed or leaf-like *Polyzoa*, consisting of two layers of cells

placed back to back, and usually more or less branched, the edges of the frond being non-celluliferous, and the cell-mouths being oval or circular.

The family of the *Cystodictyonidæ* is defined by Ulrich as comprising forms of Palæozoic *Polyzoa* in which the polyzoary consists

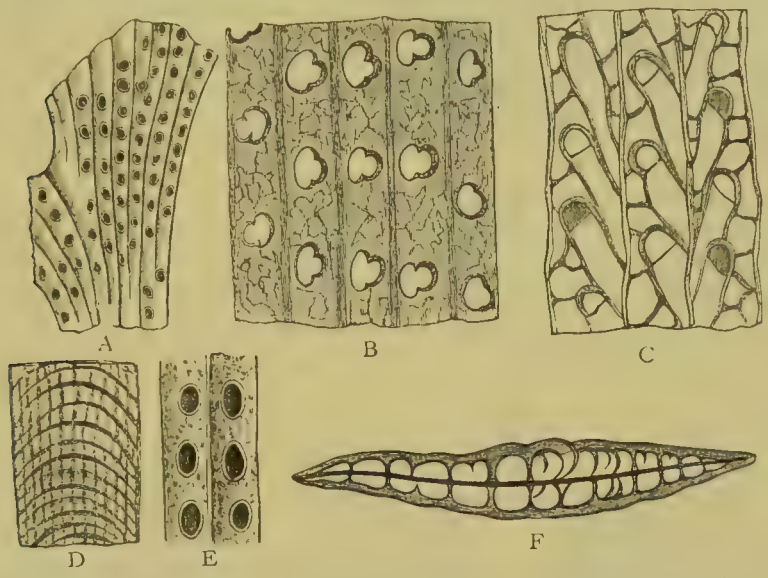


Fig. 476.—*Cystodictya Gilberti*, from the Devonian rocks of North America. A, Part of the polyzoary, enlarged (after Hall); B, Tangential section taken just below the surface, showing the trilobed apertures of the cells; C, Tangential section taken at a deeper level than the preceding, showing the interstitial vesicular tissue; D, Part of a specimen split along the median plane, enlarged; E, Part of the surface, enlarged, showing the porous intercellular tissue; F, Cross-section of the polyzoary, enlarged. (Original.)

of two layers of cells placed back to back, with tubular zoœcia, which are separated by irregular vesicular tissue. The cell-mouths have a small tooth-like projection on each side, giving the aperture a characteristic trilobed form (fig. 476, B); and the margins of the zoarium are sharp or rounded, and are non-poriferous.

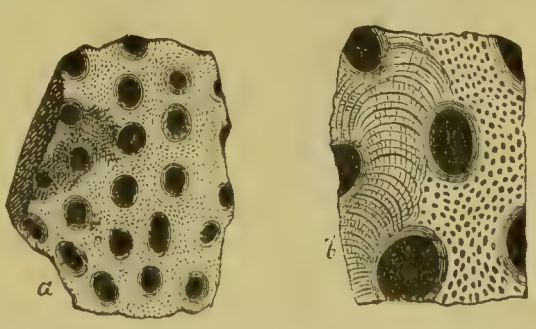


Fig. 477.—Fragment of *Coscinium* (*Coscinotrypa*) *cribriforme*, of the natural size and enlarged. Devonian, Canada. (Original.)

As an example of this family may be taken the Devonian *Cystodictya Gilberti* (fig. 476), in which the polyzoary is irregularly branched, and consists of two layers of cells which open on its opposite surfaces, and are united by a striated mesothecal layer formed by the union of the bases of the

cells (fig. 476, D and F). The cell-mouths are trilobed, and the surface in well-preserved specimens exhibits shallow interapertural pits (fig. 476, E), which in thin sections are seen to be produced by irregular vesicles occupying the intervals between the proper zoœcia (fig. 476, C). This species is abundant in the Devonian rocks of North America, but is placed by Hall in the genus *Stictopora*. The genus *Coscinium* of Keyserling (= *Coscinotrypa*, Hall) possesses an internal structure essentially similar to that of *Cystodictya*, but the polyzoary forms a wide netted expansion (fig. 477), perforated by numerous oval "fenestrules," the edges of which are sharp, and are non-celluliferous. In this genus the interstitial vesicular tissue between the zoœcia is largely obliterated by a finely tubulated calcareous deposit (fig. 455, C).

The family of the *Ceramoporidæ* has been founded by Mr Ulrich for a number of Palæozoic *Polyzoa* in which the polyzoary is usually incrusting, the cell-apertures being triangular or ovate, generally with a prominent and arched lip on one side. The type-genus of this family is *Ceramopora* itself, which ranges from the Ordovician to the Devonian, and forms thin crusts upon corals, shells, &c. The cells

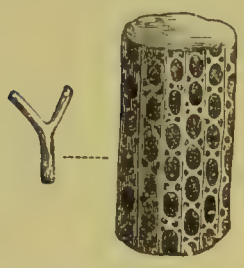


Fig. 478.—Fragment of *Rhombopora Hamiltonensis*, of the natural size and enlarged. Devonian, Canada. (Original.)

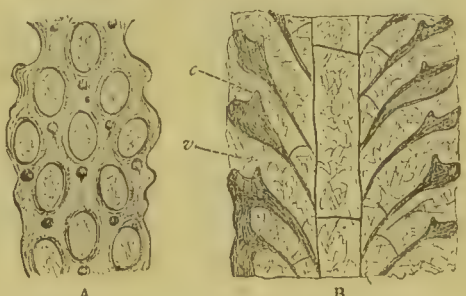


Fig. 479.—*Rhabdomeson gracile*, from the Carboniferous rocks of Scotland. A, Tangential section, enlarged. B, Vertical section, enlarged, showing the central tube: *c*, The proper cell-mouth; *v*, The outer chamber or "vestibule." (Original.)

in this genus are angular, with a strongly arched lip and oblique aperture, and they usually radiate from one or more centres of growth.

Finally, the family of the *Rhabdomesontidæ* includes a number of small Palæozoic *Polyzoa*, in which the polyzoary is ramose, and is composed of slender, cylindrical, solid or tubular branches, the cell-apertures being placed on all sides of the branches (fig. 478). The proper cell-mouth is placed at a little distance below the surface, and opens into a so-called "vestibule" or outer chamber, which constitutes the apparent cell-aperture on the surface (fig. 479, B). The cavities of the zoœcia may be crossed by a limited number of "tabulæ," and the apertures are sometimes provided with perforated "closing-plates"; while thick-walled tubes (for the support

of "avicularia"?) may be developed in the interzoœcial spaces (figs. 479, A, and 455, C).

In the genus *Rhombopora* (fig. 478) the zoœcia radiate in all directions from an imaginary axis, and the proper cell-apertures are placed at the bottom of oval or rhomboidal "vestibules." The species of this genus range from the Silurian to the Carboniferous inclusive. The genus *Rhabdomeson* is principally, if not exclusively, Carboniferous in its range, and comprises forms which are essentially similar to *Rhombopora* in general characters, but differ in the fact that the zoœcia radiate in all directions from an axial calcareous tube (fig. 479, B) running up the centre of the stems.

Sub-Order II. Cheilostomata.

In this sub-order are included all those Gymnolæmatous *Polyzoa* in which the aperture of the cell is subterminal, of less diameter than the cell itself, and usually closed by a movable lip or operculum (fig. 480). The essential character of the *Cheilostomata* is, therefore, the position of the cell-mouth on the anterior face of the zoœcium, instead of at its extremity. The aperture can also be usually closed by a semicircular movable lid, which may or may not be calcified, and which is almost always destroyed in fossilisation. The extent to which calcification of the ectocyst occurs in the *Cheilostomata* varies greatly in different types. Sometimes the polyzoary remains completely corneous (as in the *Flustridæ*), in which case it is incapable of preservation in the fossil condition; whereas in other cases the entire cell-wall may be calcified. There are many forms, however, in which an intermediate state of parts obtains, the hinder and lateral portions of the cell being calcified, while a larger or smaller area of the anterior wall, particularly in the neighbourhood of the mouth, remains in a membranous or horny state. Hence, in such cases the cells, in the fossil condition, are more or less largely open in front. In other cases, where the polyzoary is incrusting, the posterior wall of the cells may be uncalcified.

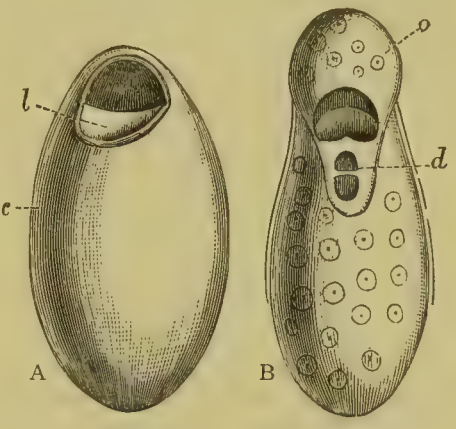


Fig. 480.—Cells of Cheilostomatous *Polyzoa*, enlarged. *c*, Ectocyst; *l*, Operculum; *o*, Ovicell; *d*, Immersed avicularium. (After Busk.)

"Avicularia" and "vibracula" are commonly developed in the *Cheilostomata*, and in the case of the living forms afford valuable characters in classification. In fossil forms, however, these minute

appendages can hardly ever be preserved, though their former existence may be inferred from the presence of "special pores" which are usually placed near the mouth, or the existence of thickened tubular supports which penetrate the substance of the polyzoary and are thus recognisable in thin sections (fig. 455, A).

The "ovicells" or marsupial pouches of the *Cheilostomata* are very characteristic structures, though they may be wanting, or may be so deeply immersed in the skeleton as to be inconspicuous. Most usually, the ovicells have the form of globular or helmet-shaped sacs (fig. 480, B) appended to the anterior end of the cells, and placed in communication with the cavity of the latter by special openings.

New cells are produced by budding from the anterior ends or lateral margins of the pre-existing cells, and all the zoœcia remain to some extent directly connected with one another. In the *Cheilostomata* generally contiguous cells are placed in communication with one another by means of perforated portions of their cell-walls ("rosette-plates"), the number and position of these structures varying in different cases. These "rosette-plates" correspond with the pores which are so commonly developed in the cell-wall of the Cyclostomatous *Polyzoa*, but their presence can only be detected in the fossil forms in cases where the condition of preservation is exceptionally good.

As regards the distribution of the *Cheilostomata in time*, it is doubtful, as previously noted, if any representatives of this sub-order have hitherto been detected in the Palæozoic rocks, though there are some Palæozoic types (such as *Paleschara*) which may belong here. On the other hand, in the Secondary rocks, from the Jurassic onwards, we meet with an abundance of the remains of Cheilostomatous *Polyzoa*, while a vast number of Tertiary forms have been described. As the characters which separate the different groups of the *Cheilostomata* are for the most part difficult of recognition, and as the classification of the group is still in a more or less unsettled condition, it will be necessary here to deal with the families of the sub-order very briefly. The arrangement here followed is, in the main, that adopted by Hincks, but only those families which from their size or palæontological significance are of special importance, are alluded to.

In the family of the *Cellulariidæ*, the polyzoary is erect and dichotomously branched, with linear divisions, composed of cells arranged in the same plane. The genus *Cellularia* has no fossil representatives, but *Scrupocellaria* (fig. 457, E) is known both by Recent and Tertiary species.

In the family of the *Cellariidæ* (*Salicornariadæ* of Busk), the polyzoary is erect and dichotomously divided, the branches being cylin-

drical, and the zoœcia disposed round an imaginary axis. The type-genus is *Cellaria* (=*Salicornaria*), in which the surface (fig. 457, c) is divided into rhomboidal or hexagonal spaces, representing the front walls of the cells; and irregularly disposed avicularia are present. The species of this genus range from the Chalk to the present day.

The family of the *Vincularidæ* is typified by the genus *Vincularia*, the species of which are Cretaceous, Tertiary, and Recent. In this genus (fig. 457, 1) the polyzoary is erect, branched, and rigid, the zoœcia being disposed alternately round an imaginary axis, and having a raised border in front.

The great family of the *Membraniporidæ* includes forms in which there is a calcareous or corneo-calcareous polyzoary, composed of horizontal and contiguous cells, the colony forming an incrusting expansion, or in some cases giving rise to an erect growth. The zoœcia are generally separated by raised margins, the front wall remaining more or less uncalcified. Owing to the membranaceous structure of the anterior walls of the cells, the front of the zoœcia in fossil specimens always appears to be more or less largely open. In the extensive genus *Membranipora* (fig. 481), the cells are surrounded by a well-marked elevated border, the space included within which is technically spoken of as the "area." The entire "area" may be occupied by a horny membrane, in which the true cell-aperture is pierced; and when this is the case, the entire "area" in the fossil condition is open. In other cases a larger or smaller part of the membrane occupying the "area" may be calcified, the remainder being left permanently soft. In these cases the "area" of the cell in fossil examples exhibits a more or less extensive deficiency or "aperture," which is always of greater size than the proper cell-mouth itself. The polyzoary in the genus *Membranipora* is always incrusting, and the numerous species of the genus range from the Chalk to the present day. A similar geological range is possessed by the genus *Biflustra*, in which the polyzoary is generally erect and foliaceous, and is typically composed of two layers of cells placed back to back.

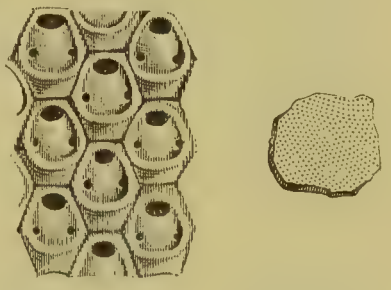


Fig. 481.—*Membranipora oceani*, showing the sub-terminal mouths of the cells. Upper Cretaceous.

In the family of the *Microporidæ* the polyzoary is incrusting, or sometimes free and unilaminar, and the zoœcia resemble those of the preceding family in being surrounded by elevated margins (fig. 482, A), but the front wall of the cells is completely calcareous. The genus *Micropora* (fig. 482, A) comprises forms in which the

cell-mouth is surrounded by a thickened border, and the species contained in it range from the Chalk to the present day.

The family of the *Cribrilinidæ* comprises forms in which the polyzoary is sometimes incrusting, sometimes free and foliaceous. The zoœcia have their front wall more or less fissured, or traversed by radiating ribs separated by intervening furrows, which may be closed or perforated (fig. 482, B). The type-genus of this family is *Cribrilina* itself (=*Lepralia* in part), of which both recent and fossil forms are known, the earliest of the latter appearing in the Cretaceous deposits.

The family of the *Microporellidæ* also includes a number of the incrusting or erect types of *Polyzoa* which were included by older

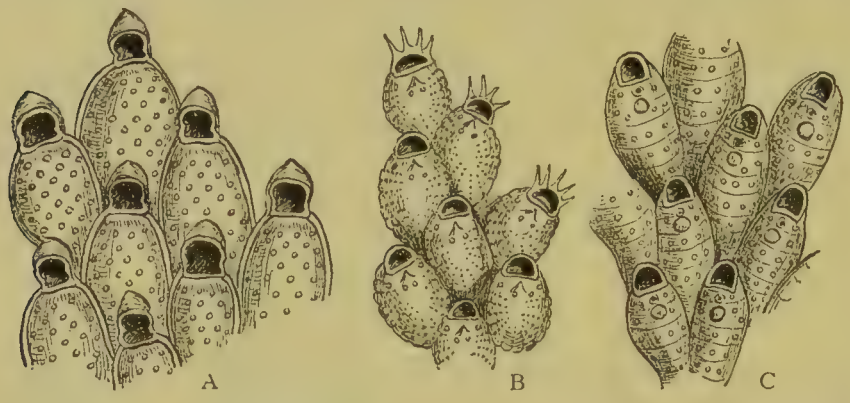


Fig. 482.—A, Cells of *Micropora complanata* (Tertiary and Recent), enlarged; B, Cells of *Cribrilina radiata* (Cretaceous, Tertiary, and Recent), enlarged; C, Cells of *Microporella impressa* (Tertiary and Recent), enlarged. (After Hincks.)

writers under the comprehensive name of *Lepralia;* the essential characters of the family being found in the fact that the cell-aperture is more or less semicircular, with an entire lower margin, while the front wall of the zoœcia exhibits a semilunate or circular "special pore" (fig. 482, C). The type-genus of this family is *Microporella* itself, the species of which are Tertiary and Recent.

The great family of the *Escharidæ* (including under this name also the *Myriozoidæ* of Hincks) comprises forms in which the polyzoary is always completely calcareous, and may be incrusting, or erect and foliaceous, or sometimes dendroid. The zoœcia are without a membranous area or raised margins, the cell-wall being entire or variously punctured, but always without special pores opening into the perivisceral cavity. In the Tertiary and Recent genus *Schizoporella* (fig. 483, B) the polyzoary is sometimes incrusting, sometimes free and foliaceous, and the lower lip of the cell-aperture has a distinct notch or sinus, representing the median pore in the *Microporellidæ*. In the genus *Hippothoa* the form of the cell-mouth is very similar to that seen in *Schizoporella*, but the zoœcia are "dis-

tant, caudate, and connected with one another by a slender prolongation of the lower extremity, so as to form a linear series" (Hincks). The earliest forms of this type appear in the Cretaceous rocks, and the genus still survives. The genus *Eschara*, as formerly understood, has been reconstructed by modern authorities, and its most

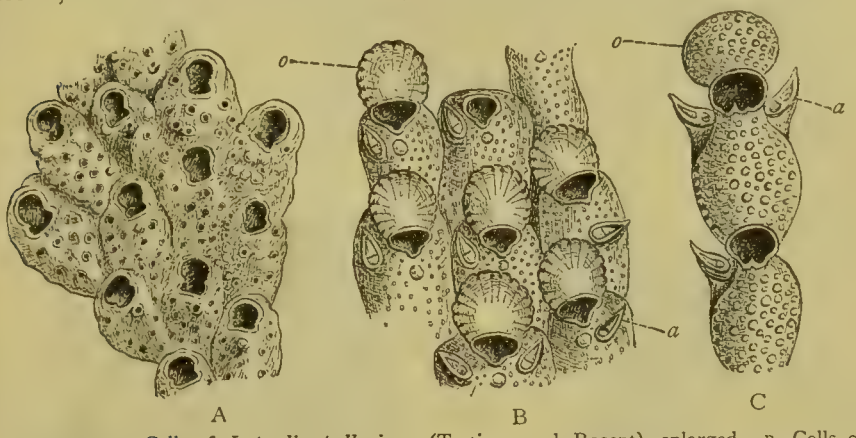


Fig. 483.—A, Cells of *Lepralia pallasiana* (Tertiary and Recent), enlarged. B, Cells of *Schizoporella unicornis* (Tertiary and Recent), enlarged. C, Cells of *Mucronella coccinea* (Tertiary and Recent), enlarged: *a*, Avicularium; *o*, Ovicell. (After Busk and Hincks.)

characteristic forms find a place in the genus *Lepralia*, as at present restricted. In this genus, the polyzoary may be incrusting or erect (fig. 484), and the foliaceous forms may be unilaminar, or may be composed of two layers of cells united back to back. The zoœcia are ovate, with a more or less horse-shoe-shaped aperture, the lower lip of which is entire (fig. 483, A). The species of this genus range from the later Secondary period to the present day. In the genus *Porella*, the original cell-mouth is semicircular, but there is formed round this a secondary and larger mouth which encloses an avicularium. The species of this genus are Tertiary and Recent. The genus *Smittia* (fig. 451, B) resembles the preceding in most characters, but the secondary mouth is elongated and is channelled in front, while the lower lip of the primary aperture is dentate. The species of *Smittia* are Tertiary and Recent. *Mucronella* is another allied genus, in which the peristome (fig. 483, C) is elevated in front into a more or less prominent mucro. The species of the genus are Tertiary and Recent.

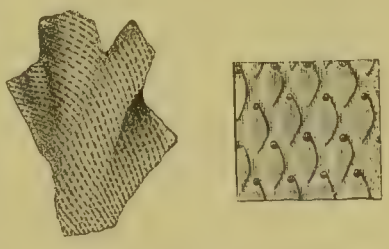
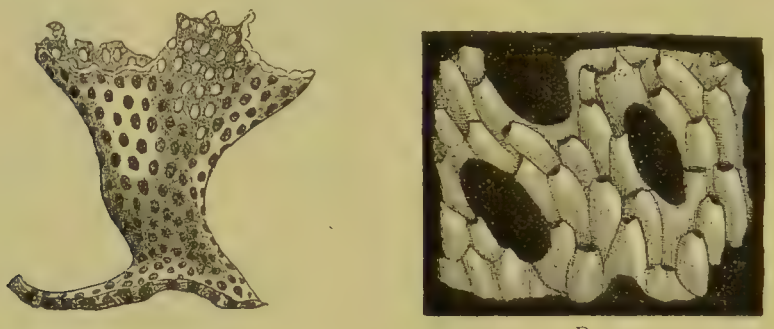


Fig. 484.—*Lepralia* (*Eschara*) *Ranvilliana*. Jurassic.

Related to the preceding, but perhaps forming the type of a separate family (*Reteporidæ*), is the genus *Retepora* (fig. 485), in

which the polyzoary is erect and calcareous, and usually has the form of a reticulate or fenestrated expansion, which is adherent by means of an incrusting base. The zoœcia are developed on the front face only of the zoarium, the dorsal surface being smooth or striated, and carrying avicularia supported upon tubercles. The cells are closely united or immersed, and on the lower margin of the cell-mouth is a prominent rostrum carrying an avicularium. The species of *Retepora* range from the Chalk to the present day.

The family of the *Celleporidæ* includes forms with a calcareous polyzoary, which may be incrusting, or ramose, or massive, and



A B

Fig. 485.—*Retepora cellulosa*, from the Red Crag (Pliocene). A, A fragment, of the natural size; B, Part of the poriferous surface, enlarged. (After Busk—copied from Zittel.)

which consists of irregularly heaped up zoœcia, which are urceolate in form and have sub-terminal mouths. The principal genus in this family is *Cellepora* itself (fig. 457, B), in which the cell-mouths have in their immediate vicinity one or more ascending rostra carrying avicularia. The genus is widely distributed in the Tertiary rocks, and numerous existing species are known.

Lastly, we have the singular family of the *Selenariidæ*, including the allied genera *Selenaria*, *Cupularia*, and *Lunulites* (fig. 457, D), in which the polyzoary is unattached, and consists of a plano-convex or concavo-convex disc, composed of only one layer of cells, the mouths of which open on the convex surface. The three genera above mentioned are the principal ones comprised in this family, and they range from the Chalk to the present day.

LITERATURE.

1. "Catalogue of the Marine Polyzoa in the Collection of the British Museum" (Cheilostomata). 1852. Busk.
2. "Catalogue of the Cyclostomatous Polyzoa in the Collection of the British Museum." 1875. Busk.
3. "Report on the Polyzoa." 'Challenger Reports,' vol. x., 1884, and vol. xvii., 1886. Busk.
4. "Monograph of the Fossil Polyzoa of the Crag." Busk. 'Palæontographical Society.' 1859.

5. "History of the British Marine Polyzoa." 1880. Hincks.
6. "Bryozoa marina in regionibus arcticis et borealibus viventia." 1867. Smitt.
7. "Kritisk förteckning öfver Skandinaviens Hafs-Bryozoer." 1864-68. Smitt.
8. "Handbuch der Palæontologie." Bd. I., Lief. 4. 1880. Zittel.
9. "Prodromus of the Zoology of Victoria" (Polyzoa). Decades III.-XIII. P. H. MacGillivray.
10. "Paléontologie Francaise" ('Terrains Cretacès et Jurassiques'). D'Orbigny. 1840-53.
11. "Polyparien des Wiener Tertiärbeckens." Reuss. 1847.
12. "Palæontologische Studien über die ælteren Tertiärschichten der Alpen." Reuss. 1869.
13. "Bryozoen des sächsischen Elbthalgebirges." 'Palæontographica,' Bd. XX. 1872-74. Reuss.
14. "Die Polyparien des Norddeutschen Tertiärgebirges." 'Palæontographica,' Bd. IX. 1863. F. A. Roemer.
15. "Die Bryozoen der böhmischen Kreideformation." 'Denkschr. d. Wien. Akad,' Bd. XXIV. 1877. Novák.
16. "Description des Bryozoaires fossiles de la formation jurassique." 'Mém. Soc. géol. France.' Ser. 2. vol. v. 1854. Jules Haime.
17. "Die Bryozoen der Maestrichter Kreidebildungen." 1851. Hagenow.
18. "Monograph of Permian Fossils." King. 'Palæontographical Society.' 1849.
19. "Synopsis of the Carboniferous Fossils of Ireland." M'Coy. 1844.
20. "British Palæozoic Fossils." M'Coy. 1851.
21. "Palæontology of New York," vol. ii., 1851, and vol. vi., 1887. James Hall.
22. "Descriptions of Bryozoa from the Palæozoic Rocks of the Western States and Territories." Prout. 'Trans. Acad. Sci. of St Louis,' vol. i.
23. "American Palæozoic Bryozoa." 'Journ. Cincinnati Society of Nat. Hist.' 1882-84. E. O. Ulrich.
24. "Contributions to American Palæontology," vol. i. 1886. E. O. Ulrich.
25. "Report on the Palæontology of Ontario." 1874. Nicholson.
26. "A Review of the British Carboniferous Fenestellidæ." 'Quart. Journ. Geol. Soc.,' vols. xxxv. and xxxvi. G. W. Shrubsole.
27. "A Review of the Family Diastoporidæ." 'Quart. Journ. Geol. Soc.', vol. xxxvi. 1880. G. R. Vine.
28. "Reports on Fossil Polyzoa." 'Brit. Association Reports." 1880-1883. G. R. Vine.
29. "New Carboniferous Polyzoa." 'Quart. Journ. Geol. Soc.,' vol. xxx., 1874. Professor John Young and Mr John Young.
30. "On new Carboniferous Polyzoa." 'Ann. and Mag. Nat. Hist.' Ser. 4. vols. xiii. and xv., 1874-75. Professor John Young and Mr John Young.
31. "Fossil Chilostomatous Bryozoa from Australia." 'Quart. Journ. Geol. Soc.', vols. xxxvii., 1881, xxxviii., 1882. A. W. Waters.
32. "On Tertiary Cyclostomatous Bryozoa from New Zealand." Ibid., vol. xliii. 1887. A. W. Waters.
33. "On Fossil Cyclostomatous Bryozoa from Australia. Ibid., vol. xl. 1884. A. W. Waters.
34. "La Faune des Bryozoaires Garumniens de Faxe." 'Ann. de la Soc. Malacologique de Belgique,' t. xxi. 1886. Pergens and Meunier.

CHAPTER XXXIV.

MOLLUSCOIDEA — continued.

Brachiopoda.

Brachiopoda (*Palliobranchiata*).—The members of this class are defined by the possession of a *body protected by a bivalve shell, which is lined by an expansion of the integument, or "mantle." The mouth is furnished with two long spirally-coiled cirriferous processes or "arms," which act as respiratory organs. The nervous system consists of an œsophageal ring, upon which infra-œsophageal and supra-œsophageal ganglia are developed. One or two pairs of tubular "nephridia" are present, which act as ducts to the reproductive organs. The sexes are distinct or united.*

The *Brachiopoda* are essentially very similar in structure to the *Polyzoa*, from which they are distinguished by the fact that they are never composite, and by the possession of a bivalve, calcareous, or sub-calcareous shell. All the living forms, except *Lingula* (*Glottidia*) *pyramidata* (fig. 486) are fixed in their adult condition to some foreign object, but many of the fossil forms seem to have been permanently free and unattached.

As regards the anatomy of their soft parts, the internal organs in the *Brachiopoda* are enclosed within two integumentary expansions which constitute the "lobes" of the "mantle," and which are generally regarded as being placed on the dorsal and ventral aspects of the body respectively. The space included between these two flaps of the integument is the "pallial cavity," the viscera and muscles being situated towards the beaks of the shell, and separated from the mantle-cavity by a membranous partition, which is perforated by the aperture of the mouth (fig. 487). The larger part of the mantle-cavity is occupied by two long oral processes, commonly spoken of as the "arms," which are the principal organs of respiration, and also serve to bring food-particles to the mouth by the cur-

rents set up by the vibrating cilia with which they are covered. The "arms" are homologous with the tentacular crown ("lophophore") of the *Polyzoa*, and have the form of lateral tubular prolongations of the margins of the mouth, usually of great proportionate length, coiled up spirally and fringed with ciliated lateral processes or "cirri" (fig. 487). In a few forms the arms can be protruded from between the opened valves of the shell, and in many types they are supported upon a more or less complicated

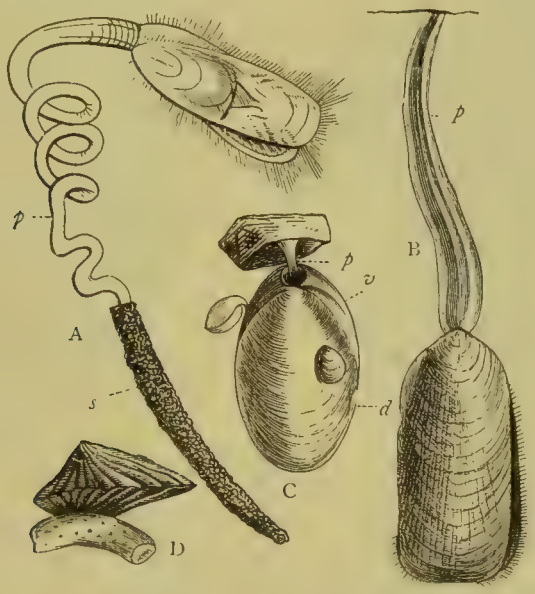


Fig. 486.—Morphology of *Brachiopoda*. A, *Lingula* (*Glottidia*) *pyramidata* (after Morse): *p*, Peduncle; *s*, Sand-tube, encasing base of peduncle. B, *Lingula anatina* (after Cuvier): *p*, The peduncle. C, *Waldheimia cranium*, with adherent young, attached to a stone (after Davidson): *p*, Peduncle; *v*, Ventral valve; *d*, Dorsal valve. D, *Crania Ignabergensis*, attached by its ventral valve to a piece of coral (Chalk).

internal calcareous framework or "loop," the structure of which will be considered in greater detail hereafter.

On the inner side of the cirri of the arms is a ciliated furrow or "brachial groove," which conducts to the opening of the mouth, and which serves for the conveyance of nutritive particles carried in the water-currents set up by the cilia. The mouth conducts by an œsophagus to a globular stomach, surrounded by a well-developed granular "liver." The intestine is sometimes short, sometimes long and coiled, and it may either terminate in a distinct anal aperture (as in *Lingula* and the other genera of Inarticulate Brachiopods), or it may end blindly in the middle line (as in *Terebratula* and the Articulate genera of Brachiopods generally). A distinct heart is present, in some cases at any rate, and has the form of a contractile

vesicle situated on the dorsal side of the stomach. The body-cavity proper is filled with a corpusculated fluid, and sends out branched prolongations into the substance of the pallial lobes. These so-

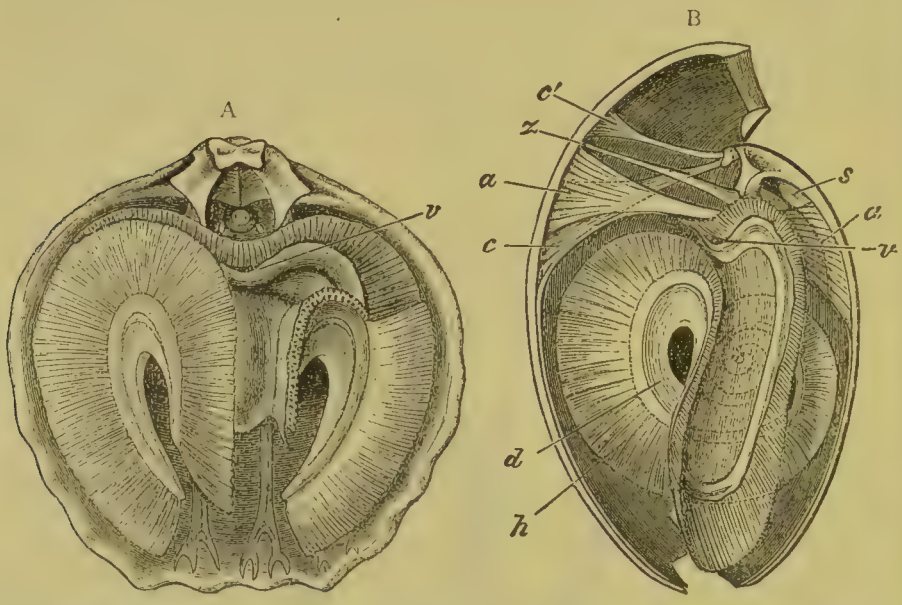


Fig. 487.—Anatomy of *Waldheimia flavescens*. A, View of the animal after the ventral valve of the shell has been removed, enlarged. B, Longitudinal section, enlarged: *d*, Spirally-coiled "arm," with lateral cirri (*h*); *a*, Adductor muscle; *c*, *c'*, Divaricator muscles; *s*, Septum; *v*, Mouth; *z*, Terminal portion of the alimentary canal. (After Davidson.)

called "pallial sinuses" often leave well-marked branching "vascular impressions" on the internal casts of the fossil Brachiopods (fig. 488).

The central nerve-system of the Brachiopods has the form of a

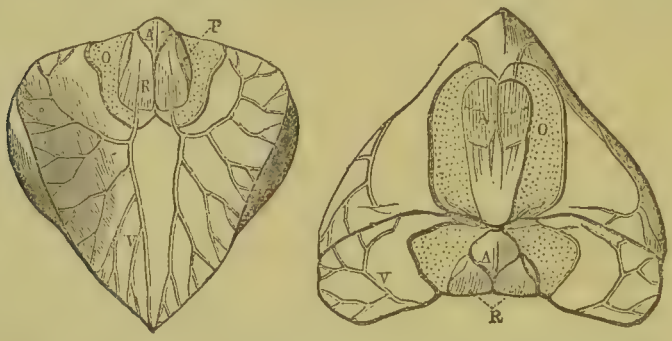


Fig. 488.—Internal cast of *Rhynchonella acuminata*, from the Carboniferous rocks, viewed ventrally and from the umbonal aspect. A, Mark left by the adductor muscle; R, Cardinal muscular impression; P, Mark left by the peduncle; V, "Vascular impressions"; O, Ovarian impressions. (After Davidson.)

circum-œsophageal ring, with a large sub-œsophageal ganglion, and sometimes small supra-œsophageal ganglia as well. The sexes are

sometimes united, but are more commonly distinct, and the reproductive elements reach the exterior by means of two or four tubular "nephridia," which open on the one hand into the body-cavity, and on the other hand into the pallial chamber. The generative glands are developed in the lobes of the mantle, and commonly leave impressions on internal casts of the shell (fig. 488, o). The embryo is ciliated and freely locomotive, but becomes fixed in the course of its development.

The *shell* of the *Brachiopoda* is essentially calcareous, but it may be largely composed of horny matter (as in *Discina*), or the carbonate of lime may be largely replaced by phosphate (as in *Lingula*).

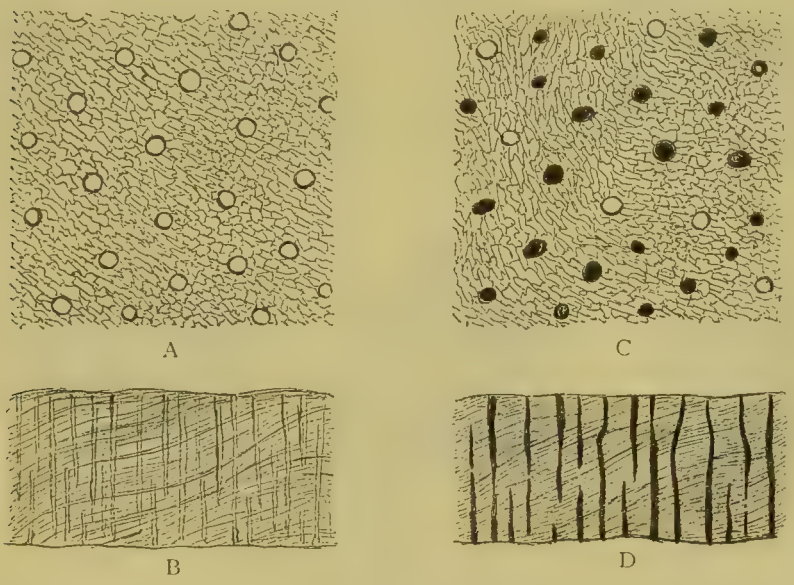


Fig. 489.—Minute structure of the shell of the *Brachiopoda*. A, Tangential section of the shell of the recent *Waldheimia flavescens*, greatly enlarged, showing the tubuli and the ends of the flattened fibrous prisms of the shell; B, Vertical section of the same, less highly magnified; C, Tangential section of the shell of *Cyrtina Hamiltonensis*, from the Devonian rocks of Canada, greatly enlarged, the tubuli being mostly filled with peroxide of iron; D, Vertical section of the same, less highly magnified. (Original.)

In the genus just mentioned, the shell consists of alternating layers of horny and calcareous composition, the calcareous layers being traversed by fine tubuli. As regards its microscopic structure, the shell of the Brachiopods consists of "flattened prisms, of considerable length, arranged parallel to one another with great regularity, and at a very acute angle—usually only about 10° or 12°—with the surfaces of the shell" (Carpenter). The oblique fibrous prisms which compose the shell are best seen in vertical sections (fig. 489, B), but their irregular and closely dove-tailed extremities are also shown in tangential sections (fig. 489, A and C). In some

types of the Brachiopods, as in the genus *Rhynchonella*, the shell-structure is simply fibrous. In many forms, however, the shell is perforated by a series of minute canals, which pass from one surface of the shell to the other, in a more or less vertical direction, being in general more or less dilated just before they reach their termination on the exterior of the shell (fig. 489, B and D). These canals give the shell a "punctated" structure, and in the living animal they contain cæcal tubuli, or solid prolongations, derived from the mantle. In some forms (as in *Producta* and *Chonetes*) the tubuli do not reach the exterior of the shell, the outer layer being simply fibrous. Though the shell is in some groups of the Brachiopods always "punctate," there are nearly allied types in which the shell may be "impunctate" in one case and "punctate" in another. Thus, the shell is simply fibrous in *Rhynchonella*, but is tubulated in the nearly related genus, or sub-genus, *Rhynchoporina*.

The two valves of the shell in any Brachiopod are articulated together by an apparatus of teeth and sockets, or are kept in apposition by muscular action alone. As regards the contained animal,

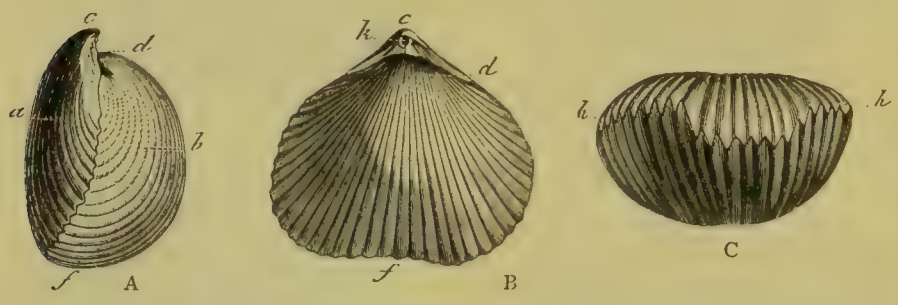


Fig. 490.—*Rhynchonella sulcata*. A, Profile view; B, View of the dorsal surface; C, View of the base. *a*, Ventral valve; *b*, Dorsal valve; *f*, Base; *c*, Beak; *k*, Foramen. Lower Cretaceous.

the position of the valves is anterior and posterior, so that they are properly termed the "ventral" and "dorsal" valves. One of the valves is always slightly, sometimes greatly, larger than the other, so that the shell is said to be "inequivalve" (fig. 490). On the other hand, a line drawn vertically from the beak of the shell to its base (in fig. 490, B, from *c* to *f*) would divide it into two equal halves, so that the shell is said to be "equilateral." In the true Bivalve Shell-fish (*Lamellibranchiata*), on the contrary, the valves of the shell are placed upon the sides of the contained animal, so that they are "right and "left," instead of being dorsal and ventral. Further, the two valves are usually of the same size ("equivalve"), and a line drawn from the beak to the base would almost always divide the shell into unequal halves; so that the shell is "inequilateral."

Ordinarily, the ventral valve of the shell of the Brachiopods is the larger of the two, and it is generally furnished with a prominent curved "beak." Very commonly the beak is perforated by a larger or smaller aperture, which is termed the "foramen" (fig. 490, B), and which serves for the transmission of a muscular peduncle or stem by which the shell is attached to some foreign object. In some cases, however (as in *Lingula*, fig. 486, B), the peduncle simply passes between the apices of the valves, and there is no foramen; whilst in others (as in *Crania*, fig. 486, D), the shell is merely attached by the substance of the ventral valve. The dorsal valve, which is also usually the smaller, is always free, and is never perforated by a foramen. Further, as already remarked, there is reason to believe that some fossil forms were free and unattached in their adult condition.

The *Brachiopoda* are divided into two primary sections according as the valves are held together by muscular action alone, and there is no "hinge" developed ("*Inarticulata*"), or as the valves are pro-

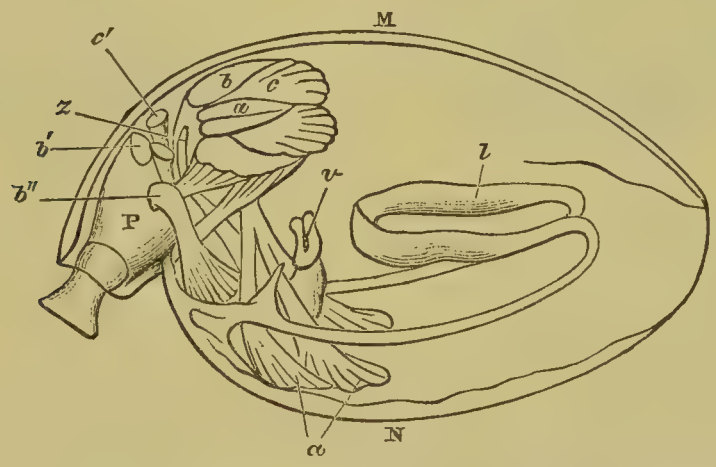


Fig. 491.—Muscular system of *Waldheimia flavescens*. M, Ventral valve; N, Dorsal valve; *l*, Loop; *v*, Mouth; *z*, Extremity of intestine; *a a*, Adductor; *c*, Divaricators; *c'*, Accessory divaricators; *b*, Ventral adjustors; *b'*, Peduncular muscle; *b''*, Dorsal adjustors; P, Peduncle. (After Hancock.)

vided with a proper "hinge" ("*Articulata*"). In the Articulated Brachiopods the valves are united at their beaks by means of two teeth which are developed on the ventral valve, and fit into corresponding sockets in the dorsal valve. Behind the dental sockets of the dorsal valve there is usually a prominent process ("cardinal process"), to which are attached the so-called "cardinal" or "divaricator" muscles (fig. 491, *c*). These are inserted on each side of the centre of the ventral valve, two pairs being usually present; and they serve to open the shell, no structure corresponding with the

"ligament" of the Bivalve Molluscs being developed. One pair of "divaricators" is of much smaller size than the other, and the name of "accessory divaricators" is given to these. The valves, on the other hand, are held together by a pair of "adductor" or "occlusor" muscles (fig. 491, *a*), which pass from one valve to the other, in the neighbourhood of the beaks. The adductors bifurcate about the middle, so as to produce a large quadrangular impression on the internal surface of the dorsal valve (fig. 492, B, *a a*) and a single divided impression towards the centre of the ventral valve (fig. 492, A, *a*). There are also, in some cases, muscles connected with the movements of the peduncle; and others (the "dorsal" and "ventral adjustors"), which have the function of erecting the shell and also that of attaching the peduncle to the shell. In the Inar-

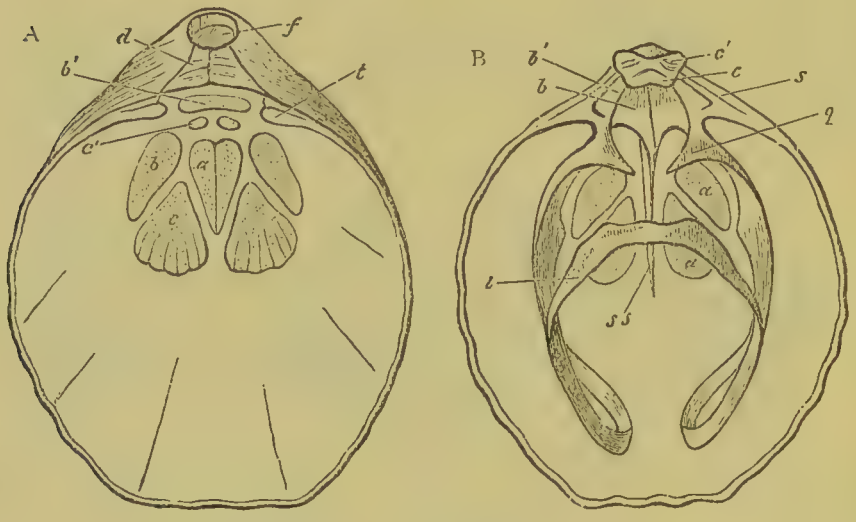


Fig. 492.—A, Interior of the ventral valve of *Waldheimia flavescens*: *f*, Foramen; *d*, Deltidium; *t*, Teeth; *a*, Adductor impressions; *c*, Impressions of the divaricator muscles; *c'*, Accessory divaricators; *b*, "Ventral adjustors"; *b'* Peduncular muscle. B, Interior of the dorsal valve of *Waldheimia flavescens*: *c c'*, Cardinal process; *b b'*, Hinge-plate; *s*, Dental sockets; *l*, Loop; *q*, Crura of the loop; *a a*, Adductor impressions; *c*, Point of attachment of the accessory divaricator; *b*, Point of attachment of the peduncular muscles; *ss*, Septum. (After Davidson.)

ticulated section of the *Brachiopoda*, as in *Lingula*, the arrangement of the muscles by which the valves are opened and shut is still more complicated.

The "arms" or "brachial processes" are in some cases simply coiled up within the shell, but in other cases, as previously noted, they are supported by a more or less complicated calcareous skeleton, which is known as the "loop" or "apophysis" (fig. 492, B). When present, the loop is always attached to the dorsal valve of the shell, and though it serves to support the brachial membrane, it does not strictly follow the course of the arms. In its simplest form, the loop is a thin ribbon-shaped calcareous lamella, the two ends of which

spring from near the hinge of the dorsal valve, while the free end of the loop is folded back upon itself (fig. 492, B). "In some genera it extends to upwards of three-fourths of the length of the shell, as in *Waldheimia;* but in others it is short, and projects but little beyond the hinge-line. In some genera it is attached only to the hinge-plate, as in *Terebratula*, *Waldheimia*, &c.; in others, to a central longitudinal plate or septum, as in *Terebratella*, &c. In certain families the apophysis presents the form of two spirally-coiled lamellæ, which nearly fill the interior of the shell; the ends of the spirals being directed outwards or towards the cardinal angles, as in *Spirifera* (fig. 493), *Athyris*, &c.; or horizontally, the apices facing each other towards the centre of the shell, as in *Glassia*. Again, the spirals are sometimes vertical, their inner sides being pressed together and flattened, with their terminations close together and facing the bottom and centre of the dorsal valve, as in *Atrypa*" (Davidson). The spiral processes are also commonly connected by a more or less complicated system of lamellæ, which vary in shape

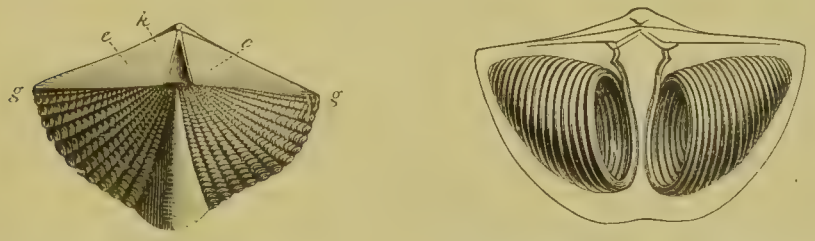


Fig. 493.—*Spirifera hysterica*—Carboniferous. The right-hand figure shows the interior of the dorsal valve, with the calcareous spires for the support of the arms. *g g*, Cardinal angles; *e*, Hinge-area; *k*, Triangular peduncular foramen.

and character in different types, and are of great value in the discrimination of certain genera. In the *Rhynchonellidæ*, the loop is represented only by two short, slender, curved lamellæ; while in some cases the sides of the loop carry minute calcareous spines, showing that even the cirri of the arms were supported by an internal skeleton. In whole families, lastly, as, for example, in the *Strophomenidæ* and *Productidæ*, the arms are entirely devoid of calcified supports.

Very commonly, the beaks of the dorsal and ventral valves of the *Brachiopoda* are separated from one another by a narrower or wider space, which is termed the "hinge-area" (fig. 493, *e*). The "area" is more or less triangular in form, generally developed on the ventral valve only, but sometimes formed by both valves conjointly, and commonly transversely striated. In such genera as *Spirifera* and *Cyrtina* the hinge-area is of very large size, but it may be very narrow, and in many cases it does not exist at all. Another structure that is commonly present in the Articulated Brachiopods

is what is known as the "deltidium." This is a triangular calcareous plate, sometimes single, sometimes composed of two lateral halves (fig. 492, *d*), which is developed in front of the foramen of the ventral valve, and may either completely enclose the foramen (as in *Rhynchonella*), or may simply form the lower boundary of this aperture. What is called a "pseudo-deltidium," again, is a triangular calcareous plate which grows downwards from the upper end of the triangular foramen in such genera as *Spirifera*, and which partially closes this opening.

As regards their *distribution in space*, all the *Brachiopoda* are marine, the number of known existing species and varieties being under one hundred and fifty. The range of the living Brachiopods in depth is very variable, even as regards individual species, some forms commonly living between tide-marks, or in quite shallow water, while others extend to depths of nearly three thousand fathoms. Upon the whole, however, the Brachiopods must be regarded as inhabitants of comparatively shallow water, since about half of the known living species are confined to depths of less than one hundred fathoms.

Leaving the problematical *Eozoön* out of sight, the Brachiopods are amongst the oldest forms of animal life, representatives of this class appearing in the Lower Cambrian deposits. Owing to the great number of fossil Brachiopods, and also owing to the fact that particular types are commonly confined to particular geological horizons, the study of this group of animals is one of great palæontological and stratigraphical importance. Out of one hundred and thirty-nine genera recorded by Davidson, one hundred and six appeared first in the Palæozoic rocks; thirty-four genera are represented in the Mesozoic deposits; and twenty-one in the Kainozoic and Recent deposits taken together. The genera *Lingula*, *Discina*, *Crania*, *Terebratula*, and *Rhynchonella* appear at some point or another in the Palæozoic series, and still exist. About eight genera are represented in the Cambrian; whereas no less than sixty-seven genera are represented in the combined Ordovician and Silurian deposits, after which the number of genera becomes progressively reduced, fifty-two generic types being present in the Devonian, forty in the Carboniferous, and twenty in the Permian. Of the known Mesozoic genera about sixteen are peculiar to this period; while of the thirteen Tertiary genera no less than twelve survive at present; and there are eight exclusively recent genera.

Upon the whole, the hingeless or Inarticulate group of the Brachiopods is the most ancient, all the Cambrian genera, with the exception of *Orthis*, belonging to this division. Of the Cambrian genera, *Lingula*, *Discina*, and *Crania* still survive. While less than one hundred and fifty species exist at present, the united Ordovician and

Silurian systems have yielded nearly two thousand species. Vast as is the number of Ordovician forms, the Silurian rocks are still more rich in this group of fossils; and the class of the *Brachiopoda* may be considered as attaining its maximum in the Silurian period, which has, for this reason, been not unaptly spoken of as the "Age of Brachiopods." In the Devonian rocks more than thirteen hundred species of Brachiopods are known, and though many of these belong to genera which were previously in existence, others belong to types, such as *Uncites*, *Stringocephalus*, *Davidsonia*, &c., which are peculiar to this system of rocks. The great genus *Terebratula* has its first representatives in the Devonian. In the Carboniferous rocks the number of species has undergone a marked reduction, the principal forms belonging to the great Palæozoic families of the *Strophomenidæ*, *Spiriferidæ*, and *Productidæ*. The genus *Producta* attains here its maximum, some of the species having an enormous geographical extension. In the Permian rocks only about thirty species of Brachiopods are known, and these belong mostly to the families of the *Productidæ* and *Strophomenidæ*.

With the beginning of the Mesozoic period, the decay of the Brachiopodous "phylum" which set in during Devonian times becomes still more pronounced. The Triassic rocks, like the Permian, exhibit a singular poverty in the remains of Brachiopods, but the group is fairly represented in both the Jurassic and Cretaceous deposits. Upon the whole, however, the reduction of the number of species which is so marked in the later Palæozoic rocks is progressively continued through the Mesozoic period. Moreover, some of the most characteristic of the Palæozoic families (the *Atrypidæ*, *Trimerellidæ*, *Productidæ*, and *Obolidæ*) have totally disappeared; while the great families of the *Strophomenidæ* and *Spiriferidæ* are only represented by a few surviving types, and disappear wholly in the Jurassic rocks. On the other hand, the families of the *Terebratulidæ* and *Rhynchonellidæ* now assume a marked predominance; the latter, however, being almost exclusively represented by species of the genus *Rhynchonella* itself. Finally, in the Tertiary rocks Brachiopods are few in number, and belong almost wholly to existing *genera*, while a number of the *species* still survive.

As regards *classification*, the *Brachiopoda* may be divided into the two orders of the *Inarticulata* and the *Articulata*, the characters and families of which will be briefly treated of in what follows.

Order I. Inarticulata

(=*Tretenterata*, *Lyopomata*, *Pleuropygia*).

This division of the *Brachiopoda* comprises those forms in which the valves of the shell are not hinged, but are held together by

muscles only, the mantle-lobes are completely free, and the intestine terminates in a distinct anus. This order includes the Palæozoic families of the *Obolidæ* and *Trimerellidæ*, and the three families of the *Lingulidæ*, *Discinidæ*, and *Craniadæ*, which commence in the Lower Palæozoic rocks and are all represented by living species at the present day.

Family 1. Lingulidæ.—In this family the animal is fixed by a muscular peduncle which passes out between the beaks of the valves (fig. 486, B). The shell is almost equivalve, oblong or ovate in form, and composed of alternating corneous and calcareous layers, the latter being phosphatic and perforated by minute tubuli. The arms are fleshy, spirally rolled, and not supported by calcified processes. The family includes the genus *Lingula* along with some allied (sub-generic?) forms, and ranges from the Lower Cambrian to the present day.

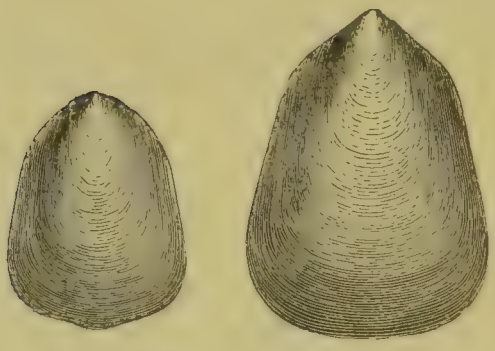


Fig. 494.—*Lingula Eva*. Ordovician. Dorsal and ventral valves. (After Billings.)

In the genus *Lingula* (fig. 494) the shell is oblong, compressed, the dorsal valve little shorter than the ventral. The shell is oval, rounded, or satchel-shaped, tapering more or less towards the beaks. The surface is concentrically striated with lines of growth. The genus commences to be represented in the Cambrian rocks, and has continued without interruption, and with no perceptible change, to the present day.

The genus, or sub-genus, *Lingulella* (fig. 495, D) differs from *Lingula* proper in the fact that there is a distinct groove in the beak of the ventral valve for the passage of the peduncle. This type comprises the oldest of British Brachiopods, *L. ferruginea* being a small form which occurs low down in the Lower Cambrian. Another species—viz., *L. Davisii*—is extremely abundant in the so-called "Lingula Flags" (Upper Cambrian). The sub-genus *Lingulepis* is very similar to *Lingula* proper, but the ventral valve is furnished with a feeble median septum. The type is the *L. pinnæformis* of the Cambrian rocks of North America.

Family 2. Obolidæ.—This family comprises forms closely allied to the preceding, but the beaks of the valves are thickened at their margin, and that of the ventral valve is provided with a groove for the passage of the peduncle. In structure, the shell is calcareo-corneous. The family is principally Cambrian, Ordovician, and Silurian, the genus *Schmidtia* surviving into the Devonian period,

and the genera *Neobolus*, *Lakhmina*, and *Schizopholis* being Carboniferous.

In the genus *Obolus* (fig. 495, B and C) the shell is orbicular, with subequal, smooth valves, the ventral valve having a longitu-

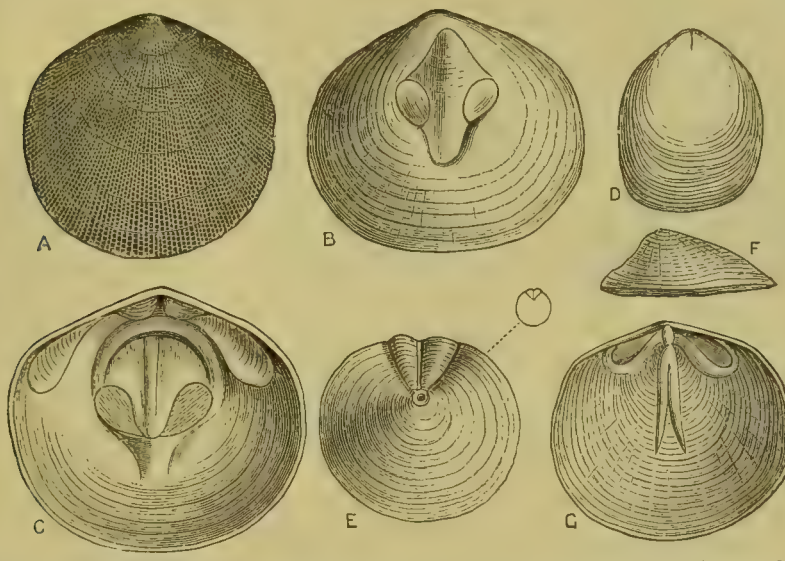


Fig. 495.—*Lingulidæ*, *Discinidæ*, and *Obolidæ*. A, *Trematis filosa*, Ordovician; B, Cast of *Obolus Davidsoni*, Silurian; C, Interior of the dorsal valve of the same; D, *Lingulella Davisii*, Upper Cambrian; E, Ventral valve of *Acrotreta Nicholsoni*, of the natural size and enlarged, and F, Side-view of the ventral valve of the same, enlarged, Ordovician; G, Interior of the dorsal valve of the same. (A is after Billings, and the other figures after Davidson.)

dinal groove for the passage of the peduncle-fibres. Usually there is a weak median septum in the ventral valve. The species of this genus are wholly Ordovician and Silurian, and are especially characteristic of the former of these systems. The little *Obolus Apollinis*

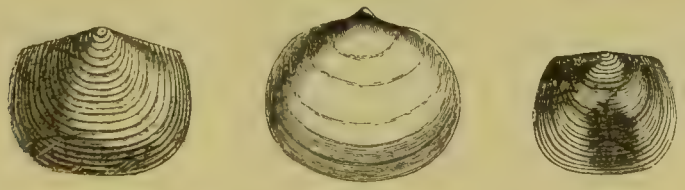


Fig. 496.—*Kutorgina cingulata*. (Billings.) Upper Cambrian.

occurs in vast numbers in the Ordovician "Ungulite Grit" of Russia.

The genus *Obolella*, of the Cambrian and Ordovician formations, is nearly allied to *Obolus*, but the arrangement of the muscular impressions is different. The genus *Kutorgina* (fig. 496) is essentially similar to the preceding, but the shell is sub-quadrate, and there is a straight hinge-line.

The genus is characteristic of the Cambrian rocks of Canada. *Schmidtia*, of the Silurian and Devonian rocks, has a minute oval shell, the ventral valve of which is convex, with a pointed beak below which an "area" is developed; and the genus *Leptobolus* of the Ordovician rocks of North America is closely allied to this, but differs in its internal characters. In the Cambrian genus *Acrothele*, the shell is nearly circular, and the ventral valve is somewhat conical, the beak being sub-central and perforated by a foramen, while the beak of the dorsal valve is marginal.

In the genus *Siphonotreta* (fig. 497) the shell is oval, inequivalve, with unarticulated valves. The beak of the ventral valve is perforated by a foramen which opens on its back, and communicates with the interior by a cylindrical tube. The surface of the shell is covered with concentric lines of growth, and furnished with numerous delicate tubular spines, which, however, are rarely preserved. All the *Siphonotretæ* at present known belong to the Ordovician and Silurian periods.



Fig. 497. — *Siphonotreta verrucosa*. Ordovician.

In the genus *Acrotreta* (fig. 495, E—G) the dorsal valve is nearly flat, and the ventral is conical and patelliform, the surface being concentrically striated. The beak of the ventral valve is perforated by a round foramen, from which a pedicle-groove extends to the posterior margin, and is bounded laterally on either side by a small false area. The genus is wholly Ordovician.

In the neighbourhood of *Acrotreta*, Dr Fischer, with some doubt, places the Silurian genus *Eichwaldia*, which has been commonly referred to the articulate family of the *Rhynchonellidæ*, but in which hinge-teeth and sockets appear to be absent. The shell in this curious genus is subtrigonal or oval, and the ventral valve has its apex perforated by a peduncular foramen, while the dorsal valve is provided with a prominent median septum. The structure of the shell is very peculiar, the most conspicuous feature connected with this being that the greater part of the surface is covered with a special alveolated layer, the hexagonal pits of which are arranged in decussating oblique lines.

Lastly, the Carboniferous rocks of India have yielded certain curious types which have been placed in this family, and have been referred to the genera *Neobolus*, *Lakhmina*, and *Schizopholis*. In all these genera the shell is of small size, and either suborbicular or trapezoidal in shape.

Family 3. Discinidæ.—In this family the shell is corneo-calcareous, with unequal valves, the animal being attached by a muscular peduncle passing through the ventral or lower valve by means of a slit in its hinder portion, or a circular foramen excavated in its substance. The arms (fig. 499) are fleshy and spirally coiled, and are not provided with calcified supports. The *Discinidæ* range from the Ordovician period to the present day.

In the genus *Discina* (figs. 498-500) the shell is sub-orbicular, with conical, nearly equal valves, of which the dorsal is the deepest, while the ventral valve is flatter, and the beaks of both are sub-central. In the typical forms of *Discina*, the ventral valve has an elongated marginal opening, which is prolonged on the surface into an anterior groove traversing the shell obliquely and terminating internally in a second groove which runs in an opposite direction to the first. In the centre of the

ventral valve is a subtriangular plate, which conceals the minute tubular foramen. In the forms which are included in the sub-genus *Orbiculoidea*, the general structure is the same as in *Discina* proper, but the valves are much elevated, and the minute foramen is situated at the posterior extremity of a groove, which is prolonged externally only, but has no internal continuation. The forms comprised in the sub-genus *Discinisca*, again, possess a longitudinal foramen situated between the beak of the

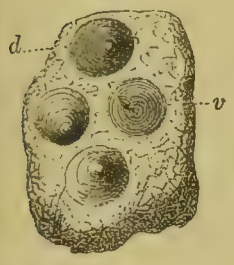


Fig. 498.—*Discina* (*Orbiculoidea*) *nitida*, from the Carboniferous rocks of North America. *d*, Dorsal valve; *v*, Ventral valve. (After Zittel.)

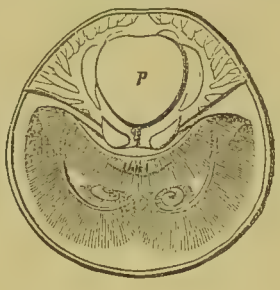


Fig. 499.—The animal of *Discina*, as seen on the removal of the ventral valve and part of the ventral mantle-lobe. *p*, Expanded surface of the peduncle. (After Woodward.)



Fig. 500.—Ventral valve of *Discina Circe*, from the Trenton Limestone (Ordovician) of Canada, showing the pedicle-groove. (After Billings.)

ventral valve and its hinder margin, in the centre of a depressed oval disc, the valve itself being flat or concave. The species of *Discina*, in the general sense, range from the Ordovician to the present day. In the genus *Trematis* (fig. 495, A) both the valves are more or less convex, and the general shape of the shell is sub-orbicular or transversely oval. The dorsal valve is the most convex, its beak being marginal, with a false "area" below it. The ventral valve is flatter, and has a wide mar-



Fig. 501.—*Crania Ignabergensis*. Cretaceous.

ginal slit for the passage of the peduncle. The surface is radiately striated, and is ornamented with small superficial pits. The species of this genus are Ordovician and Silurian.

Family 4. Craniadæ.—In this family the shell is calcareous, more or less circular in shape (fig. 501), the ventral valve being the shallowest, and being usually fixed by the substance of the test

to some foreign object. The dorsal valve is conical or limpet-shaped, and the shell in both valves is tubulated. In the interior of each valve are four principal muscular impressions, formed by the adductors, and in the interior of the ventral valve, centrally, is placed a triangular protuberance, which serves to support the bases of the fleshy arms. The family ranges from the Ordovician to the present day.

The only well-established genus in this family is *Crania* itself, which commenced to exist in the Ordovician period, and which is represented at the present day by several living species. The shell in *Crania* may be smooth, or striated with radiating ribs, sometimes with spines or foliaceous expansions, while the internal margins of the valves are expanded and often granulated. The ventral valve is fixed by its lower surface to foreign bodies, while the free dorsal valve is more or less conical (fig. 501).

In the sub-genus *Pseudocrania* (Ordovician to Devonian), the shell is only slightly inequivalve and is free, while the inner margins of the valves are smooth. In this family may perhaps be placed the singular



Fig. 502. — *Trimerella acuminata* — cast. Silurian. (After Davidson and King.)

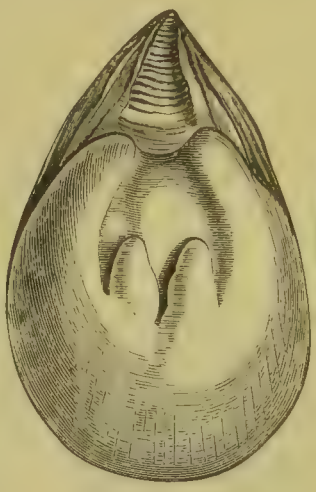


Fig. 503.—*Trimerella grandis*—cast. Silurian. (After Davidson and King.



Fig. 504. — *Monomerella prisca*—cast. Silurian. (After Davidson and King.)

Ordovician genus *Schizocrania*, in which the shell resembles *Crania* in general characters, and is fixed by the flattened ventral valve, while the dorsal valve is conical and is radiately striated. The ventral valve, however, exhibits a triangular notch on its posterior side, extending nearly to the centre, and there are six muscular impressions in the dorsal valve.

Family 5. Trimerellidæ.—This family is related to that of the *Obolidæ*, and comprises forms in which the shell is thick and cal-

careous, with unequal valves; the beaks usually prominent, or sometimes obtusely rounded, and either massive and solid, or divided by a partition into two chambers. There is a well-developed hinge-area (fig. 503), and a wide deltidium, bounded by two ridges, the inner ends of which serve as teeth, though true teeth are not present. Each valve is furnished with muscular platforms, which, in the typical species, are elevated and doubly vaulted. The principal, or only, genera of the family are *Trimerella*, *Dinobolus*, and *Monomerella*, and the family is confined entirely to the Ordovician and Silurian rocks. The differences between the above-mentioned genera depend mostly upon internal characters, which can hardly be made clear except by an examination of actual specimens, and as these very generally occur in the form of internal casts, the study of the forms of this group is attended with exceptional difficulties.

Order II. Articulata

(=*Clistenterata*, *Arthropomata*, *Apygia*).

In this order of the Brachiopods the valves of the shell are hinged, usually by means of teeth and sockets; the lobes of the mantle are not completely free; and the intestine ends blindly. This order includes the families of the *Productidæ*, *Strophomenidæ*, *Koninckinidæ*, *Spiriferidæ*, *Atrypidæ*, *Rhynchonellidæ*, *Terebratulidæ*, *Stringocephalidæ*, and *Thecidiidæ*, of which only the *Rhynchonellidæ*, *Terebratulidæ*, and *Thecidiidæ* are represented by living forms.

Family 1. Productidæ.—In this family the shell is entirely free, or is attached to submarine objects by the substance of the ventral valve or by means of spines. The valves may be regularly articulated, or may be kept in place by muscular action alone. There is a straight hinge-line, and the outer surface is more or less largely furnished with tubular spines, while the inner surface exhibits numerous funnel-shaped punctures. The arms are not provided with calcified supports, but there are well-marked muscular and vascular impressions. The ventral valve (fig. 505, *ve*) is convex, while the dorsal valve (*do*) is concave, and is furnished with a prominent cardinal process (*ca*), to which the divaricator muscles are attached. The interior of the dorsal valve exhibits a pair of large central dendritic adductor-impressions, separated by a median ridge (*a a*), a pair of reniform vascular impressions (*i*), and two shelly prominences (*p*), which probably served to support the bases of the arms. The interior of the ventral valve exhibits a pair of large dendritic adductor-impressions, situated close beneath the incurved beak, a pair of large lateral striated divaricator-impressions (*d d*), and two anterior depressions (*s*) which probably lodged the spiral arms.

All the members of the *Productidæ* are Palæozoic, the earliest forms appearing in the Silurian, while the last are found in the Permian deposits.

In the genus *Producta* (or *Productus*) itself (figs. 505-507) the valves are not articulated by teeth and sockets, and appear to have been generally free in the adult condition. In some cases, however, where the shell is furnished with long spines, it may be supposed that these structures served to moor the animal in the soft ooze of the sea-bottom. In the curious *Producta complectens*, Mr R. Etheridge, jun., has shown that the shell was firmly attached by the

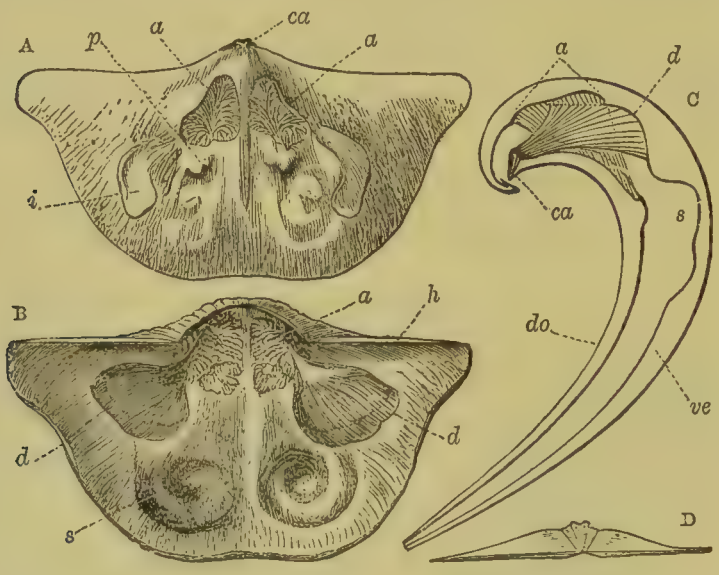


Fig. 505.—Structure of *Producta gigantea*, from the Carboniferous Limestone. A, Interior of the dorsal valve; B, Interior of the ventral valve, a portion of the projecting beak being removed; C, Ideal section of both valves, in place, in the middle line; D, Hinge-line of the dorsal valve. *a a*, Adductor impressions; *d d*, Divaricator impressions (in the ideal fig. C the letters *a* and *d* indicate the adductor and divaricator muscles respectively); *i*, Reniform vascular impressions; *p*, Processes supporting the bases of the arms; *s*, Hollows occupied by the spiral arms; *ca*, Cardinal process; *h*, Hinge-line; *do*, Dorsal valve; *ve*, Ventral valve. (After Woodward.)

twisting of some of the spines of the ventral valve round the column of a Crinoid. In the still more singular *Producta proboscidea*, the ventral valve is prolonged beyond the dorsal, and its edges are rolled together and form an elongated tube, by which the shell was attached to some foreign body. The shell in *Producta* is generally transversely elongated in shape, and is "auriculate" or furnished with ear-like expansions. There is a straight hinge-line, usually shorter than the greatest width of the shell, the hinge-area being linear or wanting. The ventral valve is convex, with a large, bent, and imperforate beak—the dorsal valve being concave, and following the curve of the former. The surface is ribbed or striated, and

the ribs carry a larger or smaller number of longer or shorter tubular spines, which are especially abundant upon the auricular expansions. The species of *Producta* range from the Devonian to the Permian, but the genus is essentially and especially characteristic of the Carboniferous period.

The genus *Strophalosia* (fig. 508, B) ranges from the Devonian to the Permian, and is distinguished from *Producta* chiefly by the fact that the

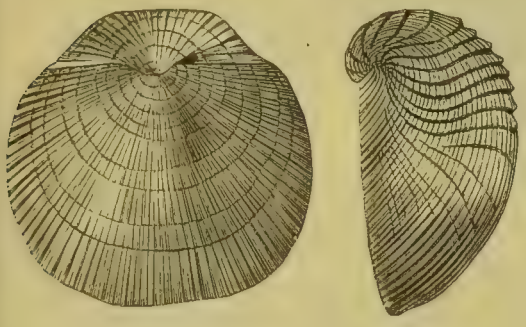


Fig. 506.—Dorsal and profile views of *Producta semireticulata*. Carboniferous.

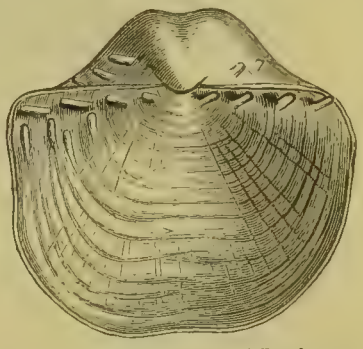


Fig. 507.—Dorsal aspect of *Producta horrida*. Permian. (After King.)

valves are not edentulous, but are articulated by teeth and sockets; while each valve has a distinct hinge-area, and the ventral valve has a foramen covered with a deltidium. *Aulosteges*, again (fig. 508, A), from the Permian, has no teeth or dental sockets—in this respect agreeing with *Producta*—but the ventral valve has a wide hinge-area, pierced by a foramen, which is covered by a convex pseudo-deltidium. *Aulosteges* is probably only a sub-genus of *Strophalosia*, but the shell is free, whereas

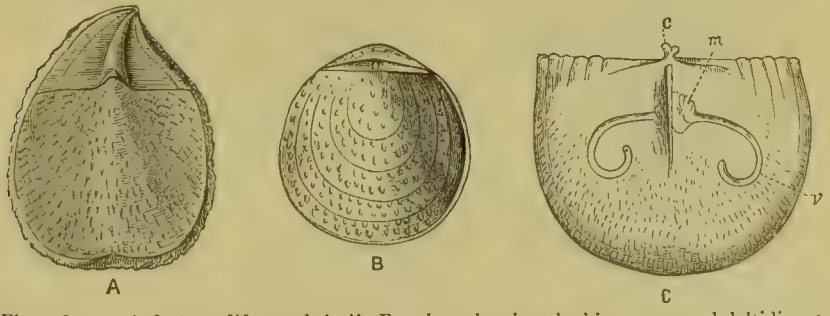


Fig. 508.—A, *Aulosteges Wangenheimii*—Permian, showing the hinge-area and deltidium; B, *Strophalosia Goldfussi*, viewed dorsally—Permian; C, *Productella onusta*—Devonian—interior of the dorsal valve, showing the cardinal process (*c*), the muscular scars (*m*), and the reniform vascular impressions (*v*). (After Davidson and Hall.)

in the latter the shell is attached by the beak of the ventral valve. Lastly, in the Devonian *Productella* (fig. 508, C) the valves are articulated by teeth and sockets, and a hinge-area is present in both valves, but the latter is narrow and linear, and the ventral valve is extremely convex and gibbous.

In the genus *Chonetes* (fig. 509) the shell is concavo-convex, trans-

versely oblong, with a straight hinge-line. The hinge-line is as wide as the shell, or the shell is eared. The ventral valve is convex, the dorsal concave, and both have a distinct hinge-area, with a central fissure, closed in the ventral valve by a pseudo-deltidium. The upper edge of the hinge-area of the ventral valve is furnished with a row of delicate

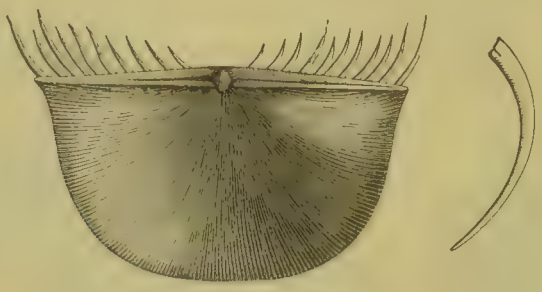


Fig. 509.—*Chonetes Dalmaniana.* Carboniferous.

tubular spines. The species of *Chonetes* are distributed in the Silurian, Devonian, and Carboniferous periods.

Family 2. Strophomenidæ.—In this great family of Brachiopods the shell is rounded or subquadrate, generally compressed, plano-convex, concavo-convex, or biconvex, the beaks being rarely prominent, and the hinge-line being straight and long. The shell seems usually to have been attached by a muscular peduncle. There is a low hinge-area in each valve, often with a triangular fissure, sometimes closed by a pseudo-deltidium, beneath the beaks. The

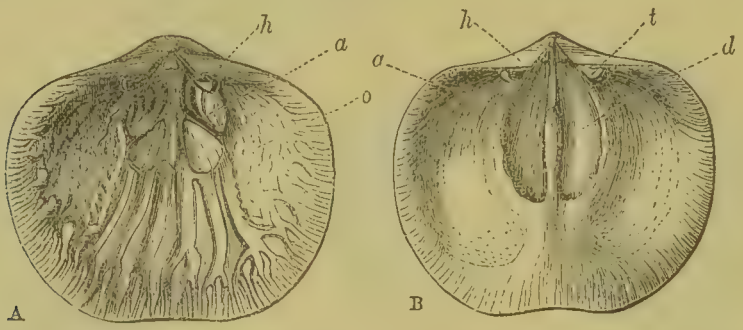


Fig. 510.—Interior of the dorsal valve (A) and ventral valve (B) of *Orthis striatula*, from the Middle Devonian of the Eifel. *h*, Hinge-area; *t*, Hinge-teeth; *a a*, Adductor impressions; *d*, Impressions of the divaricators and peduncle-muscles; *o*, Ovarian spaces. (After Davidson.)

ventral valve has two powerful hinge-teeth (fig. 510, *t*); and the dorsal valve has a prominent cardinal process, between two short brachial processes. The interior of the dorsal valve (fig. 510, A) exhibits four adductor-impressions (*a*), and well-marked vascular impressions which enclose wide ovarian spaces (*o*). The interior of the ventral valve (fig. 510, B) shows two narrow, centrally-placed

adductor-impressions (*a*), flanked by fan-shaped scars (*d*) produced by the conjoined divaricators and peduncle-muscles, the whole enclosed in a saucer-shaped depression. The arms are devoid of spiral supports, and the shell is usually penetrated by microscopic tubuli, which are comparatively large and remote.

The three principal genera of the *Strophomenidæ* are *Strophomena*,

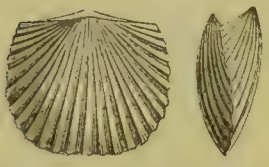


Fig. 511.—*Orthis calligramma*, var. *Davidsoni*; dorsal and side view. Ordovician.

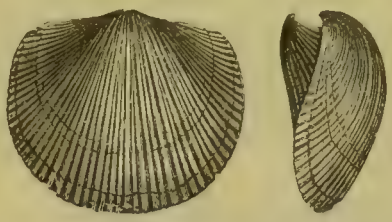


Fig. 512.—*Orthis porcata*; dorsal and side view. Ordovician.

Orthis, and *Leptæna*, and with the doubtful exception of some Mesozoic forms of the last of these, the entire family is confined to the Palæozoic period.

In the genus *Orthis* the valves are articulated by teeth and sockets, and usually are more or less transversely oblong (figs.

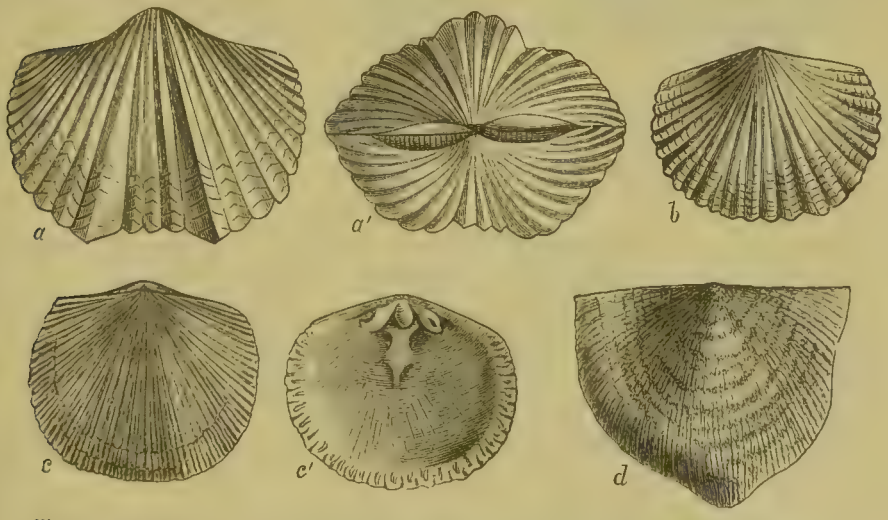


Fig. 513.—*a* and *a'*, *Orthis* (*Platystrophia*) *biforata*, Ordovician; *b*, *Orthis flabellulum*, Ordovician; *c* and *c'*, Exterior and interior of the dorsal valve of *Orthis subquadrata*, Ordovician; *d*, *Strophomena deltoidea*, Ordovician. (After Meek, Hall, and Salter.)

510-514). There is a straight hinge-line, generally shorter than the width of the shell. Each valve has a hinge-area, notched in its centre by a triangular fissure through which the fibres of the peduncle were transmitted. The shell is often more or less flattened or depressed, and the surface may be smooth, but is more commonly

ornamented with striæ, or furnished with well-marked longitudinal ribs. The species of the genus *Orthis* begin in the Cambrian, and abound in the Ordovician, Silurian, Devonian, and Carboniferous periods, especially in the first two of these; but the genus is not known to have survived the Carboniferous period. This genus is one of the most important and widely distributed groups of Palæozoic Brachiopods, and the species belonging to it may generally be distinguished from the closely related *Strophomenæ* by the fact that the shell is seldom flat, one valve being usually much more convex than the other; while the general form is compact and not extended, and the hinge-line is often shorter than the greatest width

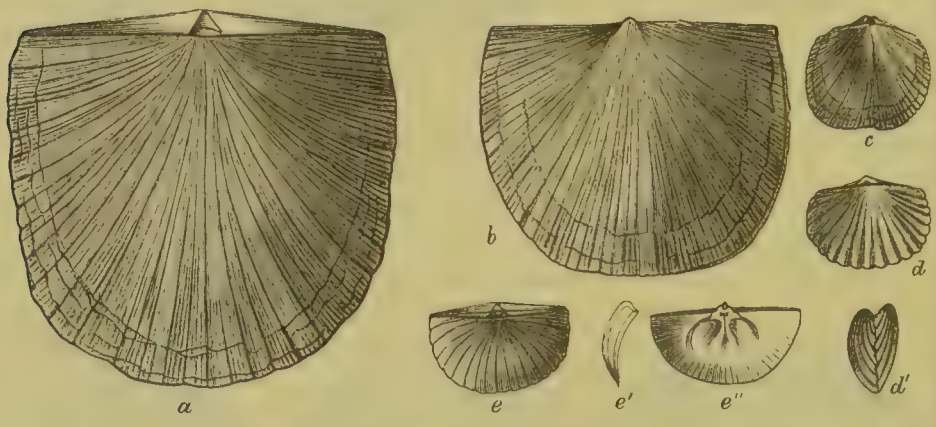


Fig. 514.—*a*, Dorsal aspect of *Strophomena alternata*, from the Ordovician of North America; *b*, Ventral aspect of *Strophomena filitexta*, Ordovician, North America; *c*, *Orthis testudinaria*, Ordovician; *d d'*, *Orthis plicatella*, Ordovician; *e e' e''*, *Leptæna sericea*, Ordovician. (After Meek, Hall, and the Author.)

of the shell. The muscular scars are quadrate, and not extended either vertically or laterally. Lastly, the "cardinal process"—that is, the projection of the dorsal valve, to which the "divaricator muscles" are attached—is undivided and linear. Though the species of *Orthis* most nearly resemble certain forms of *Strophomena*, and are very liable to be confounded with these, one or two species (such as *Orthis biforata*—513, *a*) closely simulate the genus *Spirifera* in general form.

In the sub-genus *Platystrophia*, of which *Orthis biforata* of the Ordovician rocks (fig. 513, *a*) is a characteristic form, the shell is generally transversely elongated, with a long hinge-line, both valves convex, and the ventral valve with a deep median sinus. A hinge-area and triangular deltidial fissure are present in both valves. The valves are radially plaited, and the beaks are prominent and incurved. The sub-genus ranges from the Ordovician to the Carboniferous.

The genus *Skenidium* (fig. 515, D—G) is in many respects allied to *Orthis*, but the ventral valve is much elevated, with a high triangular

area, in the centre of which is a deltoid foramen often partially closed by a pseudo-deltidium; while the dorsal valve is furnished with a prominent median septum, which is continuous with the cardinal process superiorly, and may be bifurcated at its anterior extremity. The species of *Skenidium* are Ordovician and Silurian, and it seems probable that the genus is identical with the Devonian *Mystrophora* of Kayser.

In the Silurian and Devonian genus *Tropidoleptus* (fig. 515, A—C), the

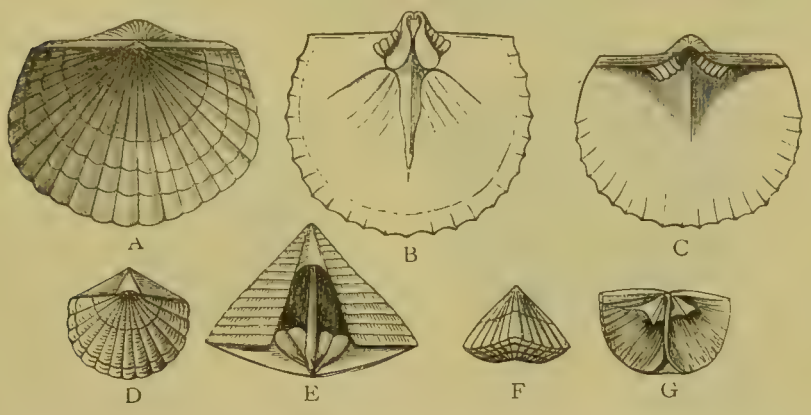


Fig. 515.—A, Dorsal view of the shell of *Tropidoleptus carinatus*, Devonian (Hamilton group) of North America, of the natural size; B, Interior of the dorsal valve of the same; C, Interior of the ventral valve of the same; D, Dorsal aspect of *Skenidium insigne*, from the Silurian (Lower Helderberg) of North America; E, Cardinal aspect of the same enlarged, showing the high area of the ventral valve, and the triangular foramen partially closed by a pseudo-deltidium; F, Base of the same; G, Interior of the dorsal valve of the same, showing the median septum. (After Hall.)

shell is concavo-convex, radiately ribbed, with a straight hinge-line and a double area, that of the ventral valve perforated by a large foramen. The ventral valve carries two strong, crenulated and diverging teeth, and the dorsal valve has two correspondingly crenulated dental sockets, a well-marked median septum, and a prominent cardinal process which almost entirely fills the foramen in the ventral valve. The species of *Tropidoleptus* are Silurian and Devonian.

In the genus *Orthisina* (= *Klitambonites* and *Hemipronites*) the shell resembles that of *Orthis*, but the ventral valve is pyramidal, and has a very high area, directed more or less at right angles to the median plane of the valves, while the dorsal valve is furnished with a smaller area. In both valves there is a triangular fissure in the hinge-area, covered by a pseudo-deltidium, that of the ventral valve being often perforated by a peduncular foramen. The typical forms of *Orthisina* are found in the Ordovician deposits.



Fig. 516. — *Orthisina Verneuili*. Ordovician.

In the genus *Strophomena* (figs. 513, 514, and 517) the shell is depressed, generally semicircular, the hinge-line as long as the width of the shell, or longer. The surface may be smooth, but is most commonly striated or ribbed. There is a double hinge-area, which is largest in the ventral valve. Each hinge-area has a median notch,

which, in the ventral valve, is partially covered by a deltidium. The ventral valve may be convex or concave, and the dorsal valve follows the curvature of the ventral valve. The species of the genus *Strophomena* are very abundant in the Ordovician, Silurian, Devonian, and Carboniferous formations, often attaining a large size; but they do not seem to have survived the close of the last-named period.

Speaking generally, the species of *Strophomena* may be distinguished from those of *Orthis* and *Leptæna*—both of which they

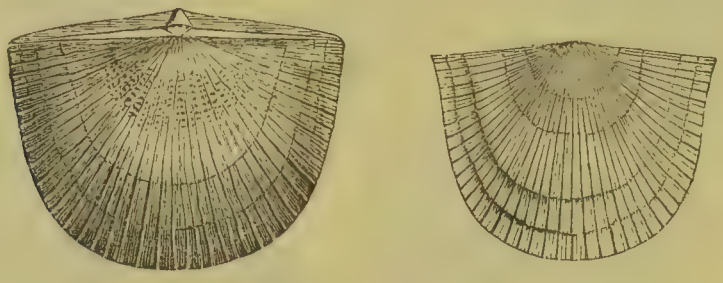


Fig. 517.—*Strophomena antiquata.* Ordovician and Silurian.

much resemble occasionally—by attention to the following points: The shell is *usually* flat and semi-oval, its length and breadth being about equal, and the hinge-line always equalling and often exceeding in length the transverse diameter of the shell. Rarely, the shell is bent and transversely extended, as in *Leptæna*. The cardinal process is large and bifid; and the muscular impressions are quadrate and laterally expanded.

The name of *Strophodonta* has been given to forms of *Strophomena* in which the hinge-line is crenulated, and there is no fissure in the hinge-

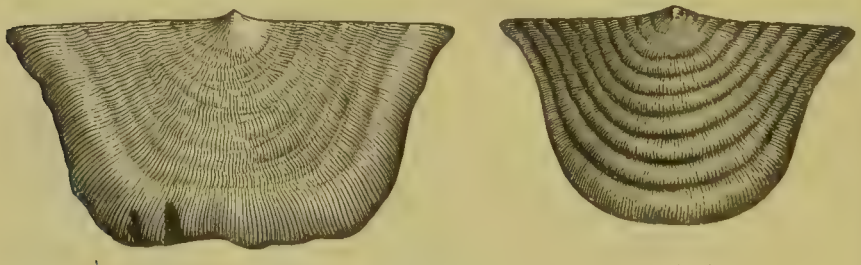


Fig. 518.—*Plectambonites* (*Strophomena*) *rhomboidalis.* Silurian.

area of the ventral valve. The name of *Plectambonites* (*Leptagonia*), again, has been given to forms of *Strophomena* in which the shell is concavo-convex, transversely semicircular, radially striated, and often concentrically wrinkled in the neighbourhood of the beaks (fig. 518). The valves in these types are generally strongly geniculated, the umbonal region being flattened, while the margins of the shell are bent towards the dorsal aspect. Forms belonging to this group are found in the Ordovician, Silurian, Devonian, and Carboniferous formations; a typical

example, and one of very wide geographical range, being the familiar *Plectambonites* (*Strophomena*) *rhomboidalis* (fig. 518), which begins in the Bala beds (Ordovician), and survived into the Carboniferous period.

The genus *Streptorhynchus* (*Orthotetes*) comprises forms like *Strophomena*, with a biconvex or concavo-convex, radially striated shell. The beak of the ventral valve is long, often twisted, with a high area and a pseudo-deltidium; the area of the dorsal valve being linear. The genus ranges from the Devonian to the Permian, characteristic species being the *S. umbraculum* of the Middle Devonian and the *S. crenistria* of the Carboniferous.

In the genus *Leptæna* are forms smaller than the majority of the *Strophomenæ*, but in many respects resembling these. The shell is more or less completely semicircular (figs. 514, *e*, and 519), transversely elongated, with a double hinge-area, notched in the centre, the fissure in the ventral valve having a deltidium, and the surface being generally striated. Speaking generally, the species of *Leptæna* can usually be separated from those of *Strophomena* or *Orthis* by the form of the transversely elongated shell, the valves of which are strongly bent, so that one (the dorsal) is always very concave, and the other (the ventral) correspondingly convex. Moreover, the muscular impressions are elongated instead of being laterally expanded, as they are in the genus *Strophomena*. The genus *Leptæna* ranges from the Ordovician to the Carboniferous. A few forms from the Lower Jurassic rocks have also been referred to the genus *Leptæna*, but some of these are now placed in the succeeding family, in the genus *Koninckella*, and it is very doubtful if the others are properly referable to *Leptæna*.

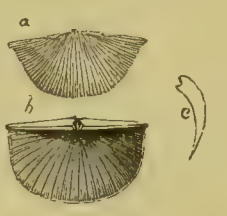


Fig. 519.—*Leptæna sericea*. *a*, Ventral valve; *b*, Dorsal valve; *c*, Section of the shell. Ordovician.

Finally, the genus *Davidsonia* includes certain singular Brachiopods, in which the shell is thick and solid, and is attached to foreign bodies by the substance of the ventral valve. The ventral valve has a wide area, with a triangular fissure covered by a convex deltidium; and though there are no calcified brachial supports, the position of the arms is indicated by two spirally-grooved elevations in the interior of the valve. The species of *Davidsonia* are found in the Devonian rocks, and the genus should perhaps be referred to the following family.

Family 3. Koninckinidæ.—This family is incompletely known, and includes small Brachiopods, in which the shell is plano-convex or concavo-convex, the hinge-line being straight or curved, and a hinge-area being absent. There may or may not be a foramen in the beak of the ventral valve, and the arms are supported upon two loosely-inrolled spiral lamellæ, the apices of the coils being directed towards the ventral valve. The typical forms of this family range

from the Devonian to the Lias, but the Silurian genus *Cœlospira* may possibly belong here.

In the genus *Koninckina*, comprising only the *K. Leonhardi* (fig. 520) of the Upper Trias, the shell is circular, concavo-convex in form, very thick, with a smooth surface and an impunctate shell-structure. The hinge-line is straight, with teeth and sockets, but without an area or deltidium. The ventral valve is very convex, and a large part of the cavity of the shell is occupied by the spirally-coiled brachial processes. Nearly allied to *Koninckina* is the Devonian genus *Anoplotheca*, in which the spirals for the arms are more largely developed than in the former.

Lastly, the genus *Koninckella* has been founded by Munier-Chalmas for the reception of some of the small Brachiopods of the Lias which



Fig. 520.—*Koninckina Leonhardi*, from the Trias of St Cassian. The left-hand figures show the ventral and dorsal aspects of the shell, of the natural size. The right-hand figure is enlarged, and shows the spiral brachial processes. (After Zittel.)



Fig. 521.—*Koninckella liasina*. Lias. The small cross below the figure indicates the real size of the shell.

were formerly referred to *Leptæna*. In this genus the shell (fig. 521) is concavo-convex, smooth, and in general aspect not unlike a *Leptæna*, but the arms are supported by spiral brachial processes of two or three coils, which carry lateral calcareous spines for the support of the cirri of the arms. The type of this genus is the *Koninckella liasina* of the Lias.

Family 4. Spiriferidæ.—In this family the shell is biconvex, its minute structure being sometimes punctated, sometimes fibrous. The arms were entirely supported upon two spirally-rolled calcareous lamellæ, which spring from the hinge of the dorsal valve—the bases of the spires being turned towards each other, while their apices are directed laterally towards the cardinal angles of the shell (fig. 493).

The family of the *Spiriferidæ* is pre-eminently Palæozoic, but several forms extend into the older Secondary rocks. No member of the family, however, has yet been found in rocks younger than the Lias. Of the genera of the family, the most important is the genus *Spirifera*, or *Spirifer* (figs. 522, 523, 524, and 526), in which the valves are articulated by teeth and sockets, and the shell is not punctated. The hinge-line is long and straight, and the well-marked hinge-area is divided across in each valve by a triangular fissure,

which in the ventral valve is closed more or less completely by a pseudo-deltidium, and in the dorsal valve is occupied by the cardinal process. The true Spirifers are mainly Silurian, Devonian, and Carboniferous, and the forms of the second of these formations often have the shell winged, or drawn out at the lateral angles (fig. 523). In the Permian rocks a few species of the genus are found. The forms included under the name of *Spiriferina* (fig. 525) range from the Devonian to the Lias, and differ from *Spirifera* proper in

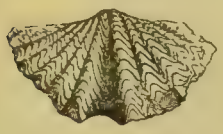


Fig. 522.—*Spirifera sculptilis.* Devonian.

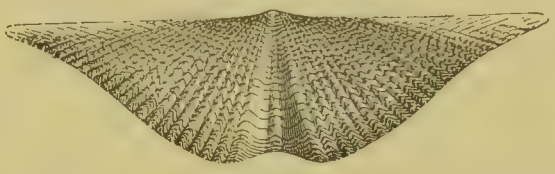


Fig. 523.—*Spirifera mucronata.* Devonian.

the fact that the shell is punctated, and in the presence of a strong median septum in the ventral valve between the dental plates, while the surface of the shell is usually covered with small tubular spines.

Suessia, of the Lias, resembles *Spirifera* in general form, and in the impunctate structure of the shell, and agrees with *Spiriferina* in the possession of a median septum between the dental plates in the ventral valve, while the "crura" of the brachial spirals are united by a transverse band. The Carboniferous *Syringothyris*, again, resembles *Spiriferina* in the punctation of the shell; but the upper ends of the dental lamellæ



Fig. 524.—*Spirifera Niagarensis.* Silurian, America.

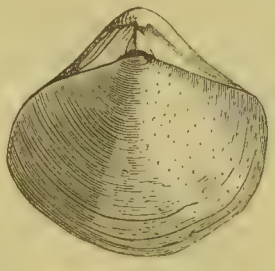


Fig. 525.—*Spiriferina rostrata.* Lias.



Fig. 526.—*Spirifera trigonalis.* Carboniferous Limestone.

are connected with two horizontal plates, which bend downwards in the middle line, and form by their apposition a tubular fissure beneath the beak of the ventral valve.

In the genus *Cyrtia* the shell resembles *Spirifera* in most respects; but the valves are very unequal, the dorsal valve is approximately flat, and the ventral valve is pyramidal, with a very large triangular hinge-area and a long and narrow foramen, which is partially closed by a pseudo-deltidium. *Cyrtina* (fig. 527, C and D) resembles *Cyrtia* in the shape of the valves, but the shell is punctate, whereas in the latter it is

impunctate. The genus *Cyrtia* is Silurian and Devonian, a familiar species being the *C. exporrecta* of the Wenlock Limestone, while the species of *Cyrtina* range from the Devonian to the Trias.

More important than either of the preceding is the genus *Athyris* (including under this head the *Spirigera* of D'Orbigny), which

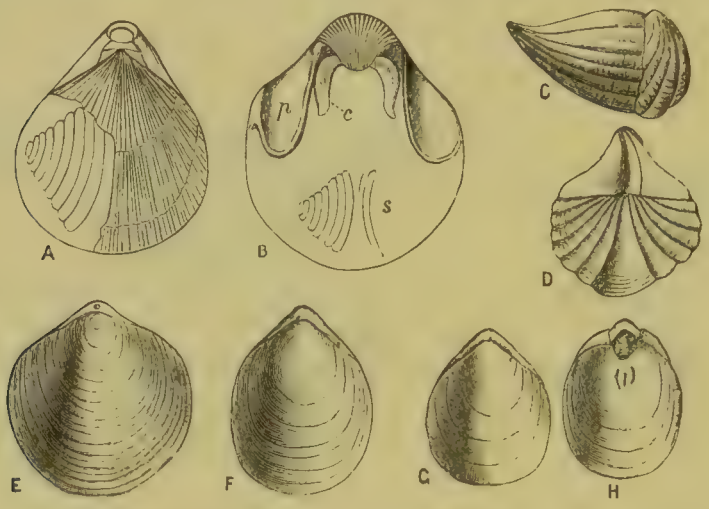


Fig. 527.—A, *Retzia serpentina*, with part of the dorsal valve removed to show the spires; *b*, *Uncites gryphus*, with the spires (*s*), from the Devonian; C, Side view of *Cyrtina heteroclita*—Devonian; D, The same viewed from the dorsal aspect; E, *Athyris concentrica*—Devonian; F, *Merista lævis* Silurian; G, *Meristella angustifrons*—Silurian, enlarged; H, Cast of the same. (After Davidson and Hall.)

ranges from the Silurian to the Trias. The shell in this genus (figs. 527, E, and 528) is convex, with unequal valves, the beak of the ventral valve being incurved, and either perforated by a small round foramen, or having the foramen concealed or closed in the adult state. (The *name Athyris*, like that of *Atrypa*, is a zoological misnomer, since in both genera the beak of the ventral valve is really perforated, in the young state at any rate. Some authorities, however, retain the name of *Spirigera* for those forms in which the foramen remains throughout life, and employ that of *Athyris* for those in which this aperture becomes closed in the adult condition, the latter having the additional distinctive character that the interior of the dorsal valve is partially divided by a longitudinal septum.) The spiral supports for the arms in *Athyris* are largely developed, and their pointed extremities are directed towards the lateral angles of the shell (fig. 528, *c*).



Fig. 528.—*Athyris subtilita*—Lower Carboniferous. The right-hand figure shows the interior of the dorsal valve, with the spiral supports for the arms. (After Dawson.)

Merista (fig. 527, F), of the Silurian and Devonian, is like *Athyris* in general characters, but there is a longitudinal septum in the ventral valve, which is supported by strongly-arched transverse plates, together forming what is known as the "shoe-lifter process." *Meristella* (fig. 527, G and H, and fig. 529) closely resembles the preceding, but the septum and supporting arched plates are wanting in the ventral valve. The genus is

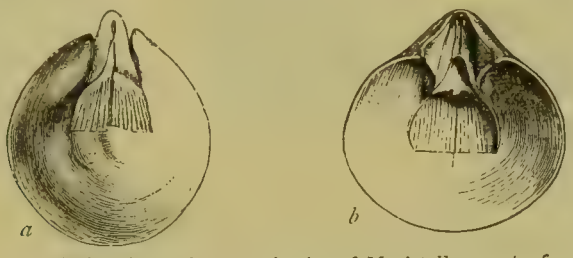


Fig. 529.—*a*, Cast of the interior of the ventral valve of *Meristella nasuta*, from the Devonian (Original); *b*, Interior of the ventral valve of the same (after Billings).

Silurian and Devonian, and a well-known and familiar species is the *Meristella tumida* of the Silurian rocks.

In the Silurian and Devonian genus *Nucleospira*, the shell has a punctated structure, with a short hinge-line, and a false area with a minute peduncular foramen beneath the beak of the ventral valve. There is a low median process in the interior of the ventral valve; and the dorsal

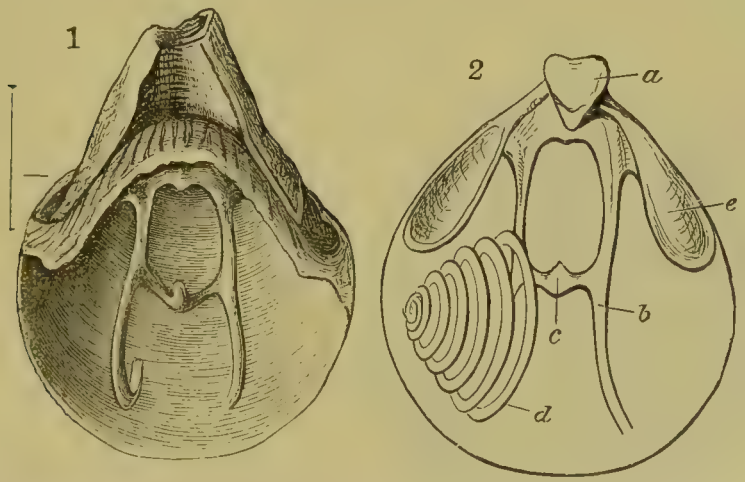


Fig. 530.—1. Interior of a specimen of *Uncites gryphus*, from the Middle Devonian, in which the greater part of the dorsal valve has been removed. The spires are destroyed, but their "crura" remain. 2. Restored interior of the dorsal valve of the same: *a*, Cardinal process; *b*, Principal stems of the spires (*d*); *c*, Band connecting the "crura" of the spires; *e*, Pouch-shaped expansions of the beaks. (After Davidson.)

valve has a spatula-shaped cardinal process, which extends upwards below the beak of the ventral valve, and to the base of which the "crura" of the brachial spires are attached.

The genus *Retzia* includes a large number of species which range from the Silurian to the Trias. The shell in this genus (fig. 527, A) is oval, usually radiately striate or ribbed, the beak of the ventral valve being

perforated by a foramen, below which is a deltidium. The shell-structure is punctated, and the brachial spires are similar to those of *Spirifera*. The names of *Trematospira* and *Rhynchospira* have been proposed for a number of Silurian and Devonian Brachiopods which are closely allied to *Retzia*, but which differ from the typical forms of this genus in some secondary characters.

Lastly, the genus *Uncites* may be placed in this family, though its characters are in some respects peculiar. The valves in *Uncites* (figs. 527, B, and 530) are convex, radially striated, and of an impunctate structure. The beak of the ventral valve is very prominent and strongly curved. The foramen in the beak of the ventral valve disappears early, and there is no true hinge-area, but a large concave deltidium is present, which partially conceals the incurved beak of the dorsal valve. The margins of the beaks are bent inwards, so as to form pouch-shaped expansions external to the hinge. Well-developed brachial processes, of the form characteristic of the *Spiriferidæ*, are present.

The genus *Uncites* is confined to the Devonian rocks, the type being the familiar *U. gryphus* of the Middle Devonian of Europe.

Family 5. Atrypidæ.—In this family the shell-structure is impunctate, and the ventral valve has an incurved beak, with a curved hinge-line and no hinge-area. The essential character of the family, however, is that the dorsal valve is provided with two spirally-coiled brachial supports, the apices of which are directed towards the interior of the valve (fig. 531). The geological range of the family is from the Ordovician to the Trias.

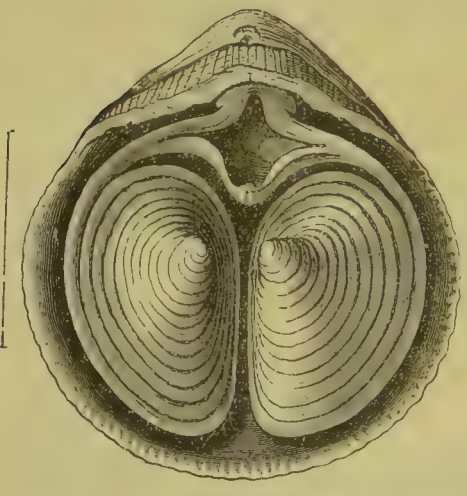


Fig. 531.—*Atrypa reticularis*, from the Silurian rocks of North America, enlarged. The greater part of the dorsal valve has been removed, to show the loop and spiral brachial processes. (After Hall.)

The type of this family is the genus *Atrypa* itself, in which the shell (fig. 532) is biconvex, generally radiately ribbed, and often ornamented with squamose lines of growth. Though named in accordance with the belief that the beak of the ventral valve was imperforate, a small foramen is really present in this genus (fig. 531), sometimes concealed, and sometimes bounded in front by a small deltidium. The spiral brachial processes are large and conical, and are directed with their apices

turned into the hollow of the capacious and ventricose dorsal valve. The species of *Atrypa* range from the Ordovician to the Trias inclusive, an exceedingly familiar and widely distributed species



Fig. 532.—*Atrypa reticularis.* Silurian and Devonian of Europe and America. (After Billings.)

being the *A. reticularis* (fig. 532) of the Silurian and Devonian rocks.

The Silurian and Devonian genus *Cœlospira* is generally regarded as a close ally of *Atrypa*. The brachial supports in this genus are of few coils, and have the peculiarity that the apices of the spires are directed towards each other. The Ordovician and Silurian genus *Zygospira* is also nearly related to *Atrypa*, but the brachial spires have their apices directed obliquely into the cavity of the dorsal valve, and point *towards* each other. On the other hand, in the genus *Dayia* (fig. 533) the spires have their apices turned obliquely into the cavity of the dorsal valve in such a manner as to point *away from* each other, thus facing the sides of the shell. The type of the genus *Dayia* is the familiar Silurian Brachiopod formerly known as *Rhynchonella navicula*, but now termed *Dayia navicula.*



Fig. 533.—Interior of the dorsal valve of *Dayia navicula*, Silurian, enlarged. (After Davidson.)

Family 6. Rhynchonellidæ.—In this family the animal is free, or attached by a muscular peduncle issuing from a foramen beneath the beak of the ventral valve. The arms are spirally coiled, and are supported at their origins only by a pair of short, curved, calcareous processes. The shell-structure is usually fibrous and impunctate, but in a few forms it is tubulated. The shell is biconvex, usually with a curved hinge-line, and a prominent pointed beak in the ventral valve. The geological range of the family is from the Ordovician to the present day, but the great majority of the genera are confined to the Palæozoic rocks.

The type-genus of this family is *Rhynchonella*, in which the valves are more or less convex, smooth, or plaited, and united by teeth and sockets. The shell (fig. 534) is trigonal, generally with a sinus in

the ventral valve and a corresponding fold in the dorsal valve, and having the beak of the ventral valve acute, incurved, and prominent. The foramen is situated beneath the beak, open to view or concealed, and entirely or partially completed by a deltidium. The numerous species of *Rhynchonella* begin in the Ordovician rocks, and the genus is well represented in the Silurian, Devonian, and Carboniferous rocks. In the Secondary series the genus exhibits a



Fig. 534.—*Rhynchonella capax;* dorsal, profile, and ventral views. Ordovician.

marked development in the Jurassic period; but there are few Tertiary species, and only six living forms are known.

The Permian Brachiopods which have been included under the name of *Rhynchoporina* resemble *Rhynchonella* in all essential respects, but the shell is punctated. In the Silurian genus *Eatonia*, hitherto only found in North America, the teeth in the ventral valve are prolonged into elevated ridges which enclose the muscular impressions, these latter being divided by a median septum, a more developed septum being present in the dorsal valve as well. In the Triassic genus *Dimerella*, again, there is a large triangular foramen beneath the beak of the ventral valve, and the dorsal valve has a prominent median septum which divides the umbonal half of the cavity of the shell into two chambers. In *Leio-*



Fig. 535.—*Leiorhynchus Huronensis*, viewed dorsally (*a*), ventrally (*b*), and in profile (*c*). Devonian. (Original.)

rhynchus (fig. 535) are various Devonian Brachiopods, very closely allied to *Rhynchonella* proper, but having the plications of the shell obsolete on the lateral angles, while well marked on the mesial fold and sinus. The beak of the ventral valve is pierced by a foramen, in at any rate the early stages of growth, and there is a well-defined septum in the dorsal valve. *Triplesia* (Silurian) has a triangular pedicle-notch beneath the beak of the ventral valve, the hinge-line being straight, with a well-defined hinge-area; while the cardinal process in the dorsal valve is prominent and bifurcated, and the shell itself is trilobate. In the Ordovician

genus *Camarella* the shell is almost equivalve, the ventral valve having an incurved imperforate beak; and the dental lamellæ converge to form beneath the beak of the ventral valve a small triangular chamber, from which a median septum is continued. A similar median septum is continued in the dorsal valve from the bases of the brachial processes. Lastly, the genus *Stenoschisma* (=*Camarophoria*, King) possesses a shell like that of *Rhynchonella*, but the teeth in the ventral valve are supported by converging lamellæ, which unite to form a low median septum, while a more pronounced septum is developed in the interior of the dorsal valve. The species of this genus are abundant in the Devonian rocks of North America, while other species occur in the Carboniferous and Permian rocks.



Fig. 536.—*Stenoschisma* (*Camarophoria*) *globulina*. Permian. (After King.)

All the preceding forms are naturally associated with one another by their structural characters; but there is another great group of Brachiopods usually placed in the *Rhynchonellidæ*, and agreeing with this family in many points, of which the genus *Pentamerus* is the type, and which presents certain distinctive features of its own. In *Pentamerus* (fig. 537) the shell is ovate, the valves articulated by teeth and sockets, and the surface generally ribbed or striated, but sometimes smooth. The beaks are incurved, that of the ventral valve concealing a triangular fissure. Inside the ventral valve "two contiguous vertical septa coalesce into one median plate, extending

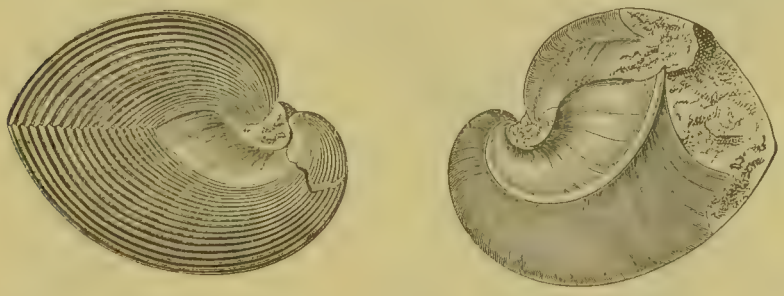


Fig. 537.—*Pentamerus Knightii*. The right-hand figure shows the internal septa and dental plates of the shell. Silurian.

from the beak to a greater or less distance; and then diverge and form the dental plates, enclosing a triangular chamber of much smaller dimensions than the lateral ones" (Davidson). The small central chamber must have been occupied by the digestive organs, and the spiral arms must have filled the great lateral spaces. In the interior of the smaller or dorsal valve are two longitudinal septa, which often form a chamber corresponding with and apposed to the median chamber in the ventral valve. The *Pentameri* are confined to the Silurian and Devonian deposits, particular species being often

restricted to definite horizons, while some forms have a very wide geographical range. Well-known Silurian species are *P. Knightii*, *P. oblongus* (fig. 538), and *P. undatus*, while *P. globus* and *P. acutolobatus* are Devonian, and the familiar *P. galeatus* is found in both sets of deposits.

In the typical forms of *Pentamerus* the shell is more or less globose, the ventral valve is much the largest, and the median septum in the same valve is very long. In certain Silurian species, however, which have been placed in *Pentamerus*, and for which Mr Billings proposed the name of *Stricklandia* (=*Stricklandinia*), the two valves (fig. 539) are



Fig. 538.—Large specimen of *Pentamerus oblongus*. Silurian. (Original.)

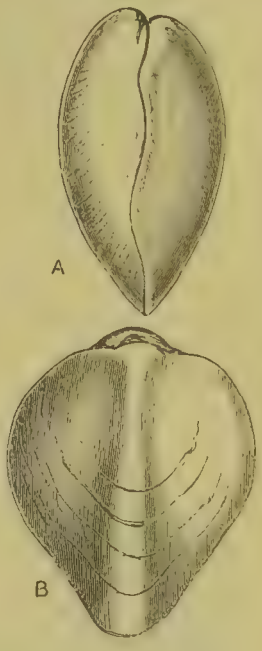


Fig. 539. — *Stricklandia Davidsoni*, viewed sideways and dorsally. Silurian. (After Billings.)

not very disproportionately unequal, the shell is often more or less depressed, and in the ventral valve there is but a short mesial septum which supports a V-shaped chamber beneath the beak; whereas in the dorsal valve there are only two short socket-plates. *Pentamerella*, *Amphigenia*, *Gypidula*, and *Anastrophia* are other generic or sub-generic titles which have been proposed for forms more or less closely allied to *Pentamerus* itself. The first three of these occur in the Devonian, but the last is found in the Silurian deposits of North America.

The genus *Porambonites* occupies a doubtful position, being sometimes placed in the present family, and sometimes referred to the *Strophomenidæ*. In this genus the shell is globose and almost equivalve, with a mesial fold and sinus in front; and the beak of the ventral valve has a small foramen. The hinge-teeth in the ventral valve are supported by strong dental lamellæ, which unite to form a small median septum.

The surface is apparently smooth, but is in reality ornamented with minute, close-set circular pits disposed in radiating lines. The species of *Porambonites* are characteristic of the Ordovician rocks, and are especially abundant in deposits of this age in the Baltic provinces of Russia.

Family 7. Terebratulidæ.—The shell in the *Terebratulidæ* is minutely punctate in structure, and is rounded or oval in form, the

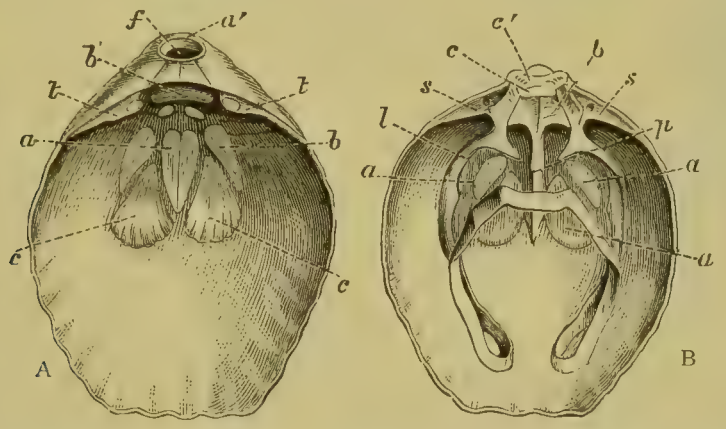


Fig. 540.—Interior of the ventral valve (A) and dorsal valve (B) of the recent *Waldheimia flavescens*. *a'*, Beak of the ventral valve with the foramen (*f*); *t*, Hinge-teeth; *p*, Septum of dorsal valve; *l*, Brachial loop; *s*, Dental sockets; *a a*, Adductor-impressions; *b b*, Ventral adjustors; *c c*, Divaricator-impressions; *b'*, Peduncular muscles; *c'*, Cardinal process. (After Davidson.)

surface being smooth or striated. The beak of the ventral valve (fig. 540, *a'*) is prominent, and is perforated by a foramen, through which passes the peduncle of attachment, and which is partially surrounded by a deltidium of one or two pieces. The arms are supported by a loop-shaped brachial process (fig. 540, *l*), which

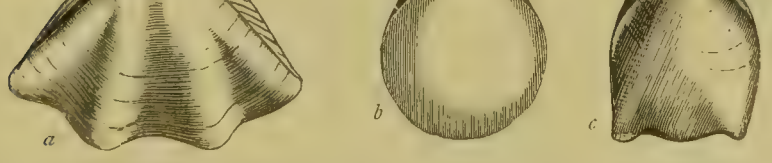


Fig. 541.—*a*, *Terebratula quadrifida*—Lias; *b*, *Terebratula sphæroidalis*—Inferior Oolite; *c*, *Terebratula digona*—Bradford Clay, Forest Marble, and Great Oolite (Jurassic). (After Davidson.)

varies in length and form in different types of the family, and which springs from the hinge of the dorsal valve. As regards its geological range, the family of the *Terebratulidæ* is represented in deposits as old as the Devonian, or even the Silurian; but it attains its maximum development in the Mesozoic and Kainozoic deposits,

and it is represented at the present day by a number of living forms.

In the genus *Terebratula* itself, as now usually restricted, the shell (fig. 541) is oval or circular, with a smooth surface, and either simply rounded in front, or exhibiting a mesial fold in the ventral valve, to which corresponds a sinus, with a lateral fold on each side, in the dorsal valve. The beak of the ventral valve is short, with a wide foramen, below which is a deltidium. The brachial loop (fig. 542) is short, and does not extend to more than a third of the distance between the hinge-line and the anterior margin of the shell. The oldest forms of the *Terebratulæ* appear in the Devonian, and other forms are found in the Carboniferous and Permian deposits. These early examples of the genus differ from later types in the possession of strong dental supports beneath the hinge of the ventral valve. Throughout the Secondary rocks, and especially in the Jurassic and Cretaceous formations, the genus is largely represented, while there is also a limited number of Tertiary types, and several living species are known.

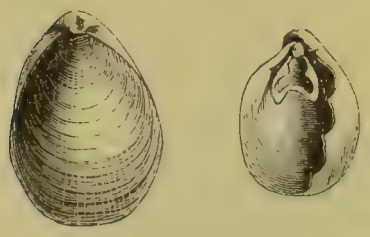


Fig. 542.—*Terebratula sacculus*—Carboniferous. The right-hand figure shows the interior of the dorsal valve with the loop. (After Dawson.)

In *Terebratulina* (fig. 543) the exterior of the shell is ornamented with dichotomous radial striæ, and the brachial loop is very short, and is converted into a simple ring. The species of *Terebratulina* range from the Jurassic to the present day.



Fig. 543.—*Terebratulina substriata*, Upper Jurassic, of the natural size. (After Zittel.)

The genus *Waldheimia* is the type of another series of the *Terebratulidæ*, in which the brachial loop is elongated, its length equalling at least half that of the shell itself (fig. 540). In addition to the presence of a long brachial loop, another distinctive character of *Waldheimia* is the existence of a more or less developed median septum in the interior of the dorsal valve. The species of *Waldheimia* appear to commence in the Lias, and the genus is well represented at the present day. There are no dental plates in the ventral valve of *Waldheimia*, but such plates are developed in the closely allied *Zeilleria* of the Jurassic, Cretaceous, and older Tertiary formations.

In the Silurian, Devonian, and Carboniferous genus *Centronella* (fig. 544), the shell has the general characters of *Terebratula*, but the brachial loop consists of two delicate ribbon-like lamellæ, which extend about one-half the length of the shell. "These lamellæ at first curve gently outwards, and then approach each other gradually, until at their lower extremities they meet at an acute angle; then, becoming united, they are reflected backwards towards the beak, in what appears to be a thin, flat, vertical plate. Near their origin each bears upon the ventral side

a single triangular crural process" (Billings). The species of this genus seem to be mainly confined to the Palæozoic rocks of North America; but European forms are known. The Silurian and Devonian genus *Leptocœlia* seems to be nearly allied to *Centronella*, but the shell is radiately-ribbed, whereas in the latter genus it is smooth. The Silurian and Devonian genera *Rensselæria* and *Meganteris* likewise include ancient types of the *Terebratulidæ*.

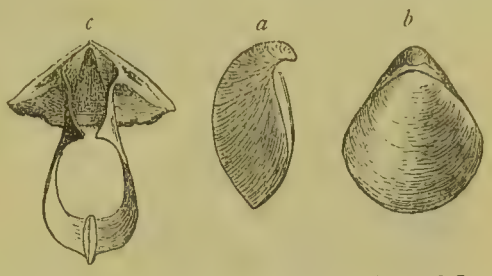


Fig. 544.—Lateral (*a*) and dorsal (*b*) views of *Centronella glans-fagea*, from the Devonian rocks of North America, of the natural size; *c*, Brachial loop of the same, enlarged. (After Hall—copied from Zittel.)

In the genus *Terebratella* (fig. 545) the shell is sometimes smooth, sometimes radiately-ribbed, and there is an incomplete deltidium (*m*) below the foramen. In the dorsal valve is a well-developed mesial septum, with which the brachial loop becomes secondarily connected by means of transverse calcareous processes, one on each side. The genus *Terebratella* begins in the Lias, is well represented in the Cretaceous formation, and still exists at the present day.

Various Mesozoic, Tertiary, and Recent Brachiopods are closely re-

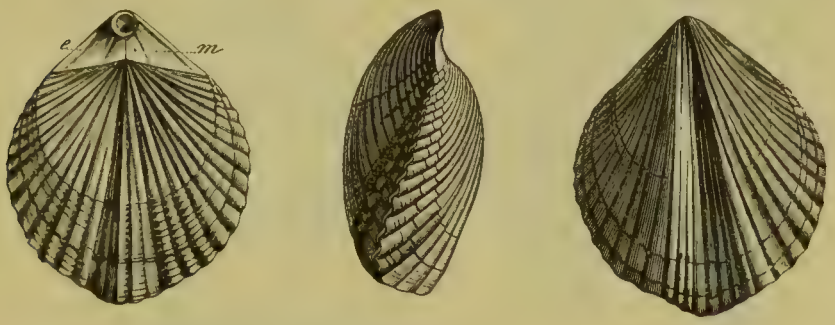


Fig. 545.—*Terebratella Astieriana*—Cretaceous. *e*, Hinge-area; *m*, Deltidium.

lated to *Terebratella*, with which they agree in the fact that the brachial loop, in addition to its normal attachment to the hinge-line, has a secondary connection with a median septum in the dorsal valve. Among the forms in question, *Lyra* (*Terebrirostra*) has a greatly elongated beak to the ventral valve, and is confined to the Cretaceous period. The genus *Trigonosemus*, also Cretaceous, has an incurved beak, a large cardinal process, and an extensive hinge-area. In the genus *Magas*, of the Cretaceous period, the dorsal septum is so greatly developed as almost to divide the cavity of the shell into two halves; while in *Megerlia* (Chalk to Recent) the brachial loop is not only attached to the hinge-plate, but is doubly connected with the dorsal septum. The Jurassic and Cretaceous *Kingena*, and the recent *Bouchardia* and *Kraussina* are other types belonging to the same group.

Family 8. Argiopidæ.—In this family there is a large foramen for the transmission of the peduncle of attachment, and the dorsal

valve is provided with one or more sub-marginal septa, with which the brachial loop becomes more or less extensively fused. The shell-structure is punctate. The range of the family is from the Jurassic period to the present day.

The type-genus of this family is *Argiope* itself, which ranges from the Upper Jurassic to the present day. In this genus the shell (fig. 546) is transversely oval, with a straight hinge-line and an area to each valve, and having a large foramen, with a rudimentary deltidium. The interior of the dorsal valve is furnished with from three to five sub-marginal septa (*s*); while the brachial loop follows the margin of the shell, and becomes attached to the septa, thus becoming four-lobed, being at the same time partially confluent with the shell. *Cistella* (Lias to Recent) closely resembles *Argiope* in general characters, but there is only a single septum in the dorsal valve, and the brachial loop is two-lobed.

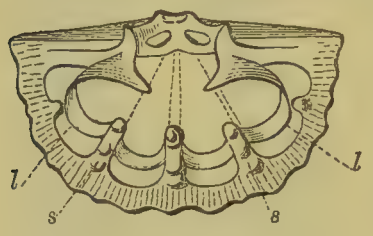


Fig. 546.—Interior of the dorsal valve of *Argiope decollata* (Recent), enlarged, showing the sub-marginal septa (*s*) and the brachial loop (*l*). (After Davidson.)

Family 9. Stringocephalidæ.—In this family the shell is rounded; the beak of the ventral valve possesses a foramen and

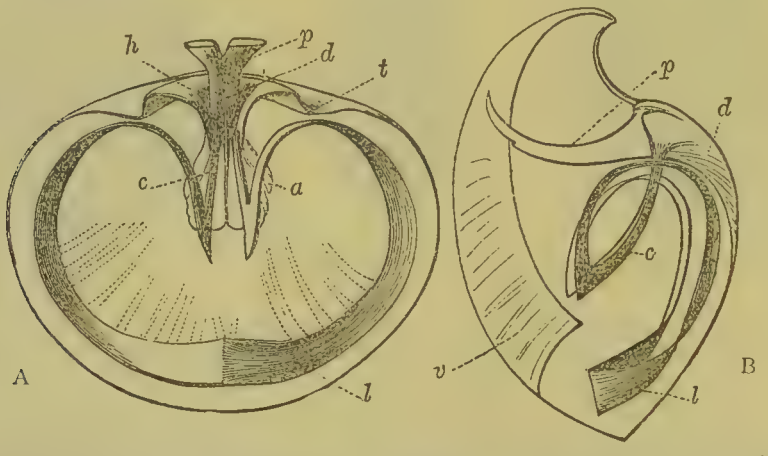


Fig. 547.—A, Interior of the dorsal valve of *Stringocephalus Burtini*, Middle Devonian; B, Shell of the same viewed in profile and showing the interior: *a*, Adductor impression; *p*, Cardinal process; *h*, Hinge-plate; *c*, Crura of loop (*l*); *d*, Dorsal septum; *v*, Ventral septum; *t*, Dental sockets. The radial processes of the loop are shown in A by dotted lines. (After Davidson.)

deltidium; the cardinal process of the dorsal valve is greatly developed; and the brachial loop is marginal, and carries internally-directed radial processes. The only genus comprised in this family is *Stringocephalus* itself, which is confined to the Silurian and Devonian rocks.

The type-species of *Stringocephalus* is the well-known *S. Burtini* of the Middle Devonian of Europe. In this well-known species (figs. 547 and 548) the shell is sub-orbicular, with a prominent beak to the ventral valve, and often growing to a great size. There is a large foramen below the beak of the ventral valve, which is triangular in the young shell, but ultimately becomes oval and reduced in size by the growth of the deltidium. The ventral valve has prominent teeth, fitting into corresponding sockets (*t*) in the dorsal valve. The cardinal process (*p*) in the dorsal valve is very prominent, and its free end is bifurcated to receive a well-developed median septum (*v*) in the ventral valve. A corresponding, but much smaller septum (*d*) is present in the dorsal valve. The hinge-plate (*h*) of the dorsal valve gives origin to a large brachial loop (*l*), consisting of two crura (*c*) which are reflected backwards about the middle of the valve, and then, bending forwards, give origin to a wide ribbon-

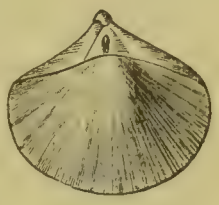


Fig. 548. — *Stringocephalus Burtini*—Devonian—reduced in size.

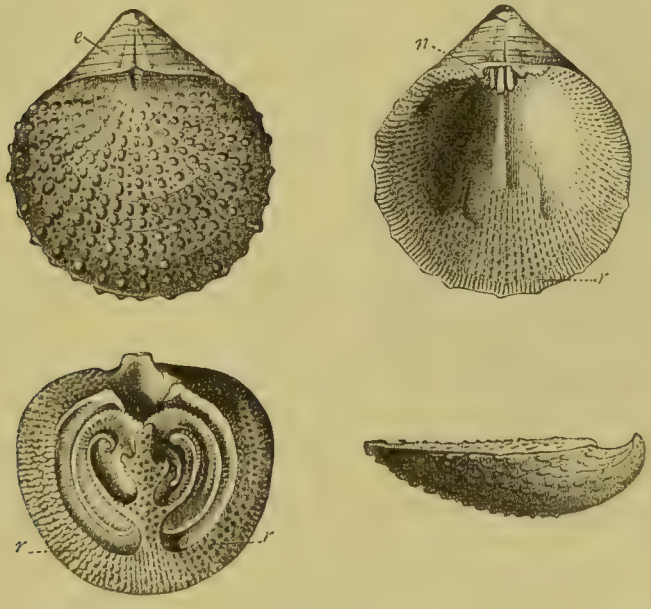


Fig. 549.—*Thecidium papillatum.* *e*, Hinge-area; *n*, Hinge-teeth of ventral valve *r r*, Granulated border of the interior of the dorsal valve. Cretaceous.

shaped band, which is sub-marginal in position, and gives off radiating shelly processes along its inner margin.

Family 10. Thecidiidæ.—In this family the shell is usually fixed to the sea-bottom by the substance of the beak of the ventral valve; the arms are united in the form of a bridge over the visceral

cavity, are folded upon themselves, and are supported by a calcareous loop; and the mantle is strengthened by a copious development of calcareous spicula. The inner layer of the shell is fibrous, but the outer layer is tubulated. The geological range of the family is from the Carboniferous to the present day.

The type-genus of this family is *Thecidium* (= *Thecidea*) which commences in the Upper Trias, is well represented in parts of the Jurassic and Cretaceous rocks, and survives under two specific forms at the present day. In this genus the shell (fig. 549) is plano-convex, and is fixed by the substance of the beak of the ventral valve, or may be free in the adult condition. The hinge-line is straight, with powerful hinge-teeth in the ventral valve, this valve being further distinguished by the presence of a large triangular hinge-area, in which is a pseudo-deltidium. The margins of both valves exhibit internally a broad granulated and thickened border. In the dorsal valve is a prominent cardinal process, flanked by the dental sockets, below which the brachial supports unite to form a slender bridge. The loop follows the margin of the shell, generally forming more or fewer lobes, and is either confluent with the shell, or is connected with a calcareous network formed by the largely developed spicula in the mantle.

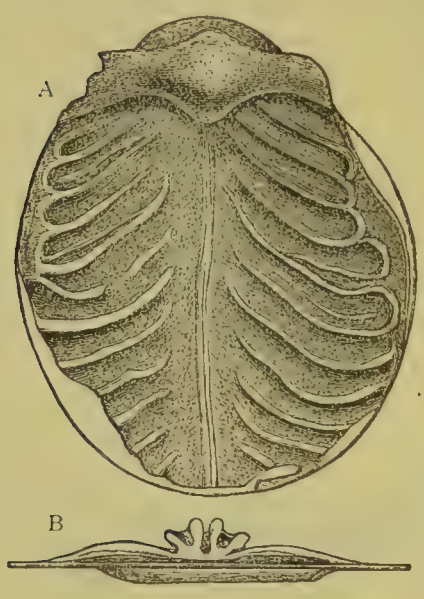


Fig. 550.—A, Interior of the ventral valve of *Oldhamina decipiens*, from the Carboniferous rocks of India; B, Cardinal view of the dorsal valve. (After Waagen.)

Besides the Liassic types included under the names of *Eudesella*, *Davidsonella*, and *Bactrynium*, this family includes the remarkable Carboniferous types described by Waagen under the names of *Oldhamina* and *Lyttonia*. In these singular forms the shell is of large size, flat or gibbous, and attached by the ventral valve. The hinge-line is straight and short, without an area or pseudo-deltidium. Internally, the ventral valve exhibits a median septum, flanked on both sides by numerous, transverse and oblique, lateral septal ridges. The dorsal valve is rudimentary, "forming together with the brachial apparatus one strongly-lobed shelly plate, which fits between the external septa of the large valve" (Waagen). These abnormal types have hitherto been detected only in the Carboniferous rocks of India, and they are regarded by Waagen as forming a special sub-family of the *Thecidiidæ*.

LITERATURE.

1. "Manuel de Conchyliologie." Paul Fischer. 1887.
2. "Manual of the Mollusca." S. P. Woodward. 4th ed. 1880.
3. "Handbuch der Palæontologie." Bd. I., Lief. 4. 1880. Zittel.
4. "Monograph of the British Fossil Brachiopoda." 'Palæontographical Society.' (With Supplements.) 1851-85. Davidson. (The first part contains a Memoir by Professor Owen on the Anatomy of Terebratula, and one by Dr W. B. Carpenter on the Intimate Structure of the Shell of the Brachiopoda.)
5. "A Monograph of Recent Brachiopoda." 'Trans. Linn. Soc.' (Zoology), vol. iv., 1886-87. Davidson.
6. "On the Earliest Forms of Brachiopoda hitherto discovered in the British Palæozoic Rocks." 'Geological Magazine,' vol. v., 1868. Davidson.
7. "On the Genera and Species of Spiral-bearing Brachiopoda." 'Geological Magazine.' Dec. II., vol. viii. 1881. Davidson.
8. "On the Trimerellidæ." 'Quart. Journ. Geol. Soc.,' vol. xxx., 1874. Davidson and King.
9. "On some Characters of Lingula anatina, illustrating the study of fossil Palliobranchs." 'Ann. Nat. Hist.,' Ser. 4, vol. xii., 1873. King.
10. "A Monograph of the Permian Fossils of England." 'Palæontographical Society,' 1850. King.
11. "Ueber Terebrateln, mit einem Versuch sie zu classificiren und zu beschreiben." Berlin, 1834. Von Buch.
12. "A Revision of the Terebratulidæ and Lingulidæ." 'American Journal of Conchology,' vol. vi., 1870. Dall.
13. "Petrefaktenkunde Deutschlands." Bd. II. Die Brachiopoden. 1871. Quenstedt.
14. "Système Silurien du Centre de la Bohème." Vol. v., Brachiopodes. 1879. Barrande.
15. "British Palæozoic Fossils." M'Coy. 1852.
16. "Figures and Descriptions of British Palæozoic Fossils." 1841. Phillips.
17. "Palæontology of New York." James Hall. Vols. i.-iv. 1843-67. Vol. iv. of this great work is specially devoted to the *Brachiopoda*, and the earlier volumes are largely concerned with descriptions of forms belonging to this class.)
18. "Reports of the State Cabinet" (the 13th, 15th, 16th, 20th, 23d, 24th, and 29th). 1860-75. Hall.
19. "Palæozoic Fossils." Vols. i. and ii., 1861 and 1874. Billings.
20. "Monographie des genres Productus et Chonetes." De Koninck. 1847.
21. "Salt Range Fossils." 'Palæontologia Indica,' 1879-85. Waagen.
22. "Bidrag till Kännedomen om Gotlands Brachiopoden." 'Öfversigt af k. Vet. Akad. Förhandl.' Bd. XVII. 1860. Lindström.
23. "Ueber die Brachiopoden der Kössener Schichten." 'Denkschr. d. k. Akad. d. Wiss. Wien.' Bd. VII. 1854. Suess.
24. "Zusammenstellung und Beschreibung sämmtlicher im Uebergangsgebirge der Eifel vorkommenden Brachiopoden." 'Palæontographica.' Bd. III. 1854. Schnur.
25. "Die Brachiopoden des Mittel- und Ober-Devon der Eifel." 'Zeitschr. d. deutsch. Geol. Gesellschaft.' Bd. XXIII. 1871. Kayser.

CHAPTER XXXV.

SUB-KINGDOM MOLLUSCA.

GENERAL CHARACTERS OF THE MOLLUSCA—GENERAL CHARACTERS OF THE LAMELLIBRANCHIATA.

THE *Mollusca* may be defined as *soft-bodied, bilaterally symmetrical, not definitely segmented animals. The anterior part of the body is very generally developed into a distinct head, bearing one or more pairs of soft tactile processes or tentacles. The mouth is anterior, the alimentary canal is completely shut off from the general cavity of the body, and the anus is primitively posterior. The nervous system consists of a small number of paired ganglia. A distinct vascular system and a systemic heart are present. One or more pairs of kidneys* (*sometimes a single kidney*) *are present as saccular organs* ("*nephridia*"), *which open internally into the body-cavity, and communicate with the exterior by a pore placed near the anus. Commonly there is an external or internal "shell."*

The body of a Mollusc exhibits a distinct dorsal and ventral surface, and a right and left side. The dorsal surface is covered by a fold of the integument which constitutes what is called the "mantle" or "pallium," and which may be greatly expanded laterally, or may form a complete sac enclosing all the viscera. The so-called "mantle-cavity" or "pallial chamber" is the space included between the lateral prolongations of the mantle and the sides of the body.

From the ventral side of the body there is, typically, developed an unpaired median muscular mass, which constitutes what is called the "foot." The foot (fig. 551, *f*) may show a distinct division into an anterior, a middle, and a posterior region; and it is often furnished with distinct lateral prolongations ("epipodia"). The foot undergoes remarkable modifications in different groups of the *Mollusca*.

The alimentary canal commences at the mouth (fig. 551, *m*),

which may or may not be provided with an apparatus of teeth, or may be furnished with tactile processes. The digestive tube is commonly of considerable length, and usually shows a gullet, into which salivary glands pour their secretion, a stomach, and an intestine. The rectum terminates at the anal aperture (fig. 551, *a*), which is primitively at the hinder end of the body, but which in many forms ultimately becomes shifted further forward. The blood is colourless; and a definite heart, consisting of a ventricle and one or two

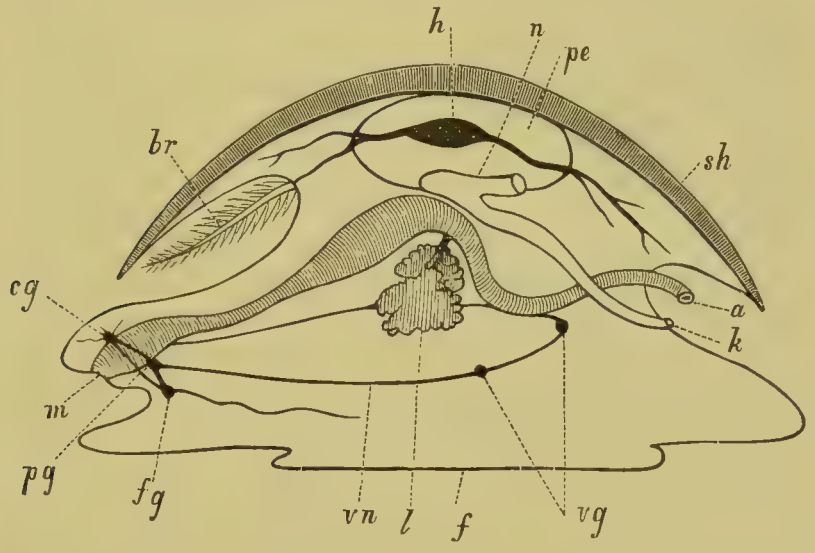


Fig. 551.—Diagram of a Mollusc (altered from Lankester). *m*, Mouth; *a*, Anus; *l*, Liver; *f*, Foot; *sh*, Shell, attached to the mantle; *h*, Heart; *pe*, Pericardium; *n*, Kidney, opening internally into the pericardium, and externally near the anus (*k*); *br*, Gill; *cg*. One of the cerebral ganglia, connected by commissures with the pleural ganglion (*pg*) and the pedal ganglion (*fg*); *vn*, Visceral nerve-cord extending backward, and carrying visceral ganglia (*vg*).

auricles, is always present, and always has the function of propelling the aerated blood through the body.

Respiratory organs are not always developed, the function of respiration being in some cases discharged by the thin walls of the mantle-cavity. In the majority of the Molluscs, however, there are definite respiratory organs, a portion of the mantle being specialised for this purpose. In the *Lamellibranchiata*, and the branchiate *Gastropoda*, the breathing-organs are in the form of lamellar or pectinate gills; and the same is the case with the *Cephalopoda*. In the pulmonate *Gastropoda*, in which respiration is aerial, a pulmonary sac or air-chamber is produced by the folding of a portion of the mantle, over the interior of which the pulmonary vessels are distributed, and the external opening of which is placed on the side of the neck.

The nervous system consists of paired ganglia united by com-

missures. The most important ganglia are (1) a pair of "cerebral" ganglia, placed above the gullet; (2) a pair of "pedal" ganglia placed below the gullet, and supplying the foot and adjacent parts; and (3) a group of "visceral" ganglia placed towards the posterior part of the body.

Reproductive organs are always present, and the sexes may be distinct or united. There is usually a well-marked metamorphosis in development, and the embryo very commonly passes through a "trochosphere" stage, in which it swims about actively by means of a circlet of cilia placed in front of the mouth, and closely resembles the larva of many Annelides. The young Mollusc possesses a glandular involution of the dorsal integument, which produces an embryonic shell, and this may either be cast off as development proceeds, or may remain permanently as part of the shell of the adult. In the Spiral Gastropods the embryonic shell or "nucleus" is placed at the apex of the permanent shell, whereas in the Bivalves it is situated at the beak or "umbo."

The Molluscs very generally develop an integumentary skeleton in the form of a "shell," which in all forms, except in the Argonaut, is secreted by the mantle. In chemical composition the shell consists of carbonate of lime disseminated throughout an organic matrix. The atomic arrangement of the carbonate of lime differs in different cases, some Molluscs having the shell wholly composed of calcite, while in others it is wholly composed of aragonite, and in many forms it consists of an inner layer of aragonite and an outer layer of calcite. Very generally the outer surface of the shell is covered by an easily recognisable horny external layer (the "epidermis" or "periostracum"), but this may be exceedingly thin, or may disappear altogether in the course of growth. Some of the more important points in the microscopic structure of the shell will be briefly noticed in dealing with the different groups of Molluscs. While the presence of a shell is very characteristic of the Molluscs, there are many so-called "naked" forms, in which the adult is either totally devoid of a shell, or possesses only a rudimentary shell enclosed in the substance of the mantle.

The *Mollusca* may be roughly divided into two great sections, respectively termed the *Acephala* and the *Encephala* (or *Cephalophora*), characterised by the absence or presence of a distinctly differentiated head. The headless, or Acephalous, Molluscs correspond to the class *Lamellibranchiata;* also distinguished, at first sight, by the possession of a bivalve shell. The Encephalous Molluscs are more highly organised, and are divided into the two principal classes of the *Gastropoda* (including the *Pteropoda*) and the *Cephalopoda*, with which may be associated the two small and aberrant groups of the *Polyplacophora* (Chitons) and *Scaphopoda*

(Tooth-shells). The shell in the Encephalous Molluscs is of a very different nature in different cases, but all the members of this section possess a complicated series of lingual teeth, and they have for this reason been grouped together by Professor Huxley under the name of *Odontophora*.

As regards their *distribution in space*, all the members of the *Mollusca* are aquatic in their habits with the exception of a portion of the Pulmonate Gastropods, many of these, however, being inhabitants of water, though others are strictly terrestrial. The water-inhabiting Molluscs may live in the sea, or in brackish or fresh waters. Owing to their generally living in water, and owing also to their so commonly possessing hard structures, whether external or internal, no fossils are more abundant or more important than the remains of the *Mollusca*. As regards the general *distribution in time* of the Molluscs, all the principal classes (viz., the *Lamellibranchiata*, *Gastropoda*, and *Cephalopoda*) are represented in the Upper Cambrian deposits, and it is therefore clear that we have at present no knowledge of the really primordial types of the sub-kingdom. Speaking generally, the chief representatives of the *Mollusca* in Palæozoic time are the chambered Cephalopods (*Tetrabranchiata*), the Dibranchiate Cephalopods apparently not having come into existence, while the Lamellibranchs and Gastropods show a comparatively limited development. In Mesozoic time, the Dibranchiate Cephalopods make their first appearance, and undergo a vast development, while the Tetrabranchiate division of this class has also a wonderful representation. The Lamellibranchs are very largely represented in the Mesozoic deposits, but the Gastropods still play a subordinate part. In Kainozoic time, on the other hand, the Cephalopods undergo an extraordinary reduction, the group of the Tetrabranchiates becoming almost extinct, while the Lamellibranchs and Gastropods, the latter particularly, assume a predominant position. At the present day, the Lamellibranchs and Gastropods are the two leading classes of Molluscs, and both seem to have attained their culminating point in existing seas.

Class I. Lamellibranchiata.

The *Lamellibranchiata* (= *Conchifera* or *Pelecypoda*) are often familiarly spoken of as the "Bivalve Molluscs," and are characterised by *the absence of a distinctly differentiated head, and by having the mantle divided into two lobes, right and left, each of which secretes a shelly investment, so that the body is more or less completely enclosed in a bivalve shell. There are one or two pairs of lamellar gills on each side of the body. An odontophore is wanting. The sexes are distinct or united.*

The body in the Lamellibranchs is bilaterally symmetrical, and is enclosed in a largely developed "mantle" or "pallium," which is divided into two lateral halves, the right and left "lobes" of the mantle. The two lobes of the mantle are united along the dorsal side of the body, and are prolonged laterally as two great flaps, which conceal the body, and enclose inferiorly a chamber known as the "mantle-cavity." The lower or ventral edges of the mantle-lobes are normally free; but in many Bivalves they become more or less fused with one another (fig. 552), so that the animal is enclosed in a complete sac, in which certain openings are left anteriorly and posteriorly. Two of these apertures are at the posterior end of the animal, and serve to permit the ingress into the mantle-cavity of the water required for respiration and for the purpose of obtaining food, and the egress of the same. The lower or ventral aperture is inhalant in function; the upper or dorsal aperture is exhalant; and the anus is always placed in the vicinity of the latter, so that excrementitious matters are carried away in the out-going currents of water. In many cases these two openings into the mantle-sac are drawn out into longer or shorter muscular tubes, which are known as the "siphons." In those Bivalves which have the ventral margins of the mantle-lobes *free*, the in-going and out-going currents of water still enter and leave the mantle-cavity by openings at its posterior end.

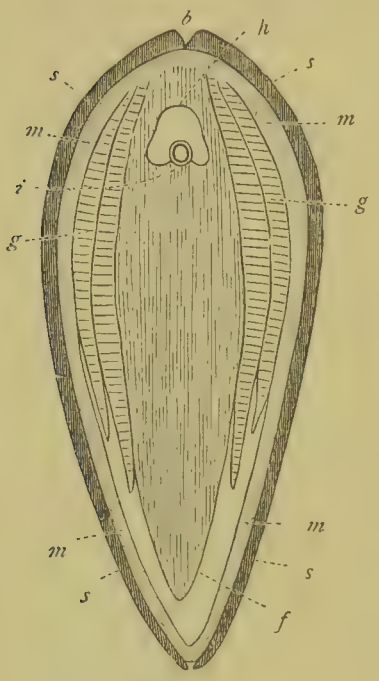


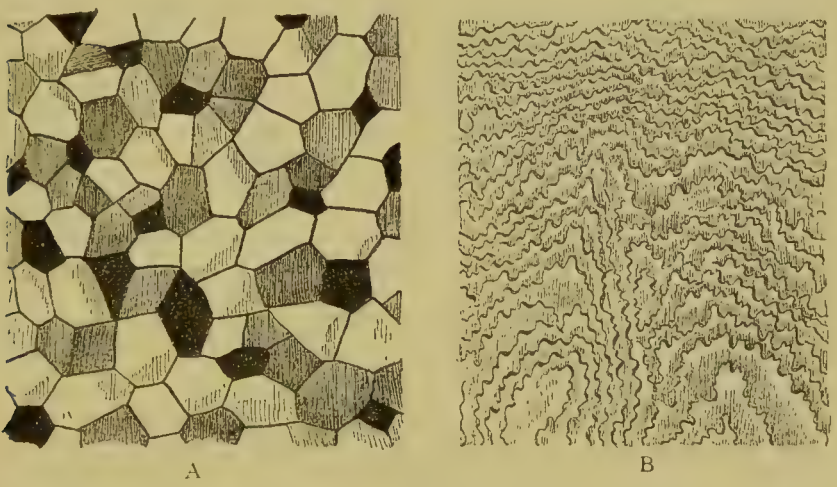
Fig. 552.—Diagrammatic vertical and transverse section of *Mya arenaria*. *b*, Back, or "dorsal margin" of the shell; *s s*, The two valves of the shell, right and left; *m m*, The two halves, or "lobes," of the mantle, producing the shell; *g g*, The gills, two pairs on each side; *h*, The heart; *i*, Intestine; *f*, The foot.

In those Bivalves which have the mantle-lobes fused along their ventral edges, a third aperture is necessary in order to allow of the protrusion of the "foot." This aperture is always placed ventrally and towards the anterior end of the animal. In the forms with free mantle-lobes no special opening is needed for the protrusion of this organ.

The "foot" of the Bivalves is not so extensively developed as in the Gastropods. Usually it forms a hatchet-shaped muscular organ, which may be used in locomotion, but is hardly ever adapted for crawling. In other cases it is cylindrical in shape, and in the

sedentary Bivalves it is more or less completely aborted. In many cases, especially in the young, there is developed, on the under surface of the foot, in the middle line, a peculiar "byssal gland." This gland secretes a viscid material which is moulded into threads by grooves on the external surface of the foot, and which gives rise to a tuft of silky fibres (the "byssus"), serving to moor the animal to foreign objects, and often having a special notch or aperture in the shell for its emission.

The *shell* of the Bivalves is the result of the deposition of lime-salts in the outer layer of the mantle, chiefly along its ventral margins; and as the mantle is divided into a right and left "lobe," so the shell also is divided into a right and left "valve." The outer surface of the shell is usually covered by thinner or thicker horny "epidermis" or cuticle, but this may become obsolete in the adult. The calcareous tissue of the shell itself is very generally disposed in two distinct strata, of which the outer is prismatic, and the inner is



A B

Fig. 553.—A, External surface of *Pinna*, showing the ends of the prisms of the outer shell-layer, greatly enlarged; B, Polished surface of mother-of-pearl, enlarged eighty-five times. (After W. B. Carpenter.)

laminated. The outer prismatic layer is secreted by the free edges of the mantle-lobes, and grows, therefore, at the circumference of the shell only. It consists, in the majority of cases, of polygonal calcareous prisms, placed side by side in close contact, and directed perpendicularly to the surface of the shell. Hence sections of this layer taken parallel with the surface exhibit the transversely-divided prisms as a pavement of hexagonal or polygonal cells; and the same appearance is seen on examining the surface of this layer under a sufficient magnifying power (fig. 553, A). The prisms of the outer layer of the shell vary considerably in diameter, length, regularity, and precise mode of arrangement in different Bivalves. The inner

layer of the shell is laminated, and is secreted by the whole outer surface of the mantle. Hence, this stratum is produced in successive layers throughout the entire life of the animal, each new layer extending a little beyond the one last formed; and in this way are produced the concentric "lines of growth," which are so characteristic of the shells of the Bivalves. The calcareous laminæ composing the inner layer of the shell are disposed approximately parallel to the surface. In many cases (fig. 553, B) the laminæ are very delicate, and are more or less crumpled or undulated, so that when the minute undulations of the successive layers of this stratum are exposed on the surface, the rays of light are broken up in such a way as to give rise to the iridescence and play of colours characteristic of "mother-of-pearl" or "nacre." In other cases, however, the laminæ of this internal stratum are thicker, and are not minutely undulated, and this layer then assumes a "porcellanous" character.

As regards the chemical composition of the shell in the Bivalves, considerable differences obtain as to the precise condition in which the carbonate of lime presents itself. In some cases (as, for example, in *Ostrea*), both the outer and inner layers of the shell are composed of calcite, whereas in others both layers are formed of aragonite. In other cases, again (as in *Pinna*), the outer prismatic layer is composed of calcite, while the inner laminated layer is formed of aragonite. Owing to the greater destructibility and instability of aragonite as compared with calcite, these differences in composition lead to considerable differences in the mode of preservation of different types of the Bivalves. Thus, forms in which the shell is wholly composed of aragonite are often represented in the fossil state solely by moulds and casts; while in those in which the two layers of the shell differ in composition, the inner aragonite-layer of the shell may have been wholly removed, while the outer calcite-layer may be well preserved.

Though the Bivalves agree with the *Brachiopoda* in possessing a shell which is composed of two pieces or valves (small accessory plates are present in *Pholas*, &c.), there are, nevertheless, many points in which the shell of a Lamellibranch is distinguished from that of a Brachiopod, irrespective of the great difference in the structure of the animal in each. The shell in the *Brachiopoda*, as we have seen, is rarely or never quite equivalve, and always has its two sides equally developed (equilateral); whilst the valves are placed antero-posteriorly as regards the animal, one in front and one behind, so that they are "dorsal" and "ventral." In the *Lamellibranchiata*, on the other hand, the two valves are usually of nearly equal size (equivalve), and are more developed on one side than on the other (inequilateral); whilst their position as regards the animal is always *lateral*, so that they are properly termed "right" and "left" valves, instead of "ventral" and "dorsal."

It is to be remembered, however, that many of the Bivalves, such as the Oysters, habitually lie on one side, in which case the valves, though really right and left, are called "upper" and "lower." It is to be borne in mind, also, that the two valves, especially in the attached Bivalves, may be very unsymmetrical, one valve being much larger or deeper than the other. Lastly, there are some cases (*e.g.*, *Pectunculus*) in which the shell becomes very nearly equilateral, the line drawn from the beaks to the base dividing the shell into two almost equal halves.

The following are the chief points to be noticed in connection with the shell of any Lamellibranch (fig. 554): Each valve of the shell may be regarded as essentially a hollow cone, the apex of which is turned more or less to one side; so that more of the shell is situated on one side of the apex than on the other. The apex of the valve is called the "umbo," or "beak," and is mostly turned towards the mouth of the animal. Consequently, the side of the

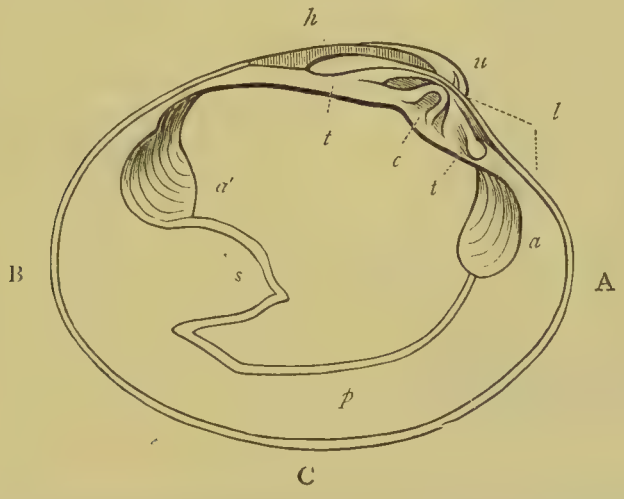


Fig. 554.—Left valve of *Cytherea chione*. (After Woodward.) A, Anterior margin; B, Posterior margin; C, Ventral margin or base. *u*, Umbo; *h*, Ligament; *l*, Lunule; *c*, Cardinal tooth; *t t*, Lateral teeth; *a*, Anterior adductor; *a'*, Posterior adductor; *p*, Pallial line; *s*, Pallial sinus, caused by the retractor muscles of the siphons.

shell towards which the umbones are turned is the "anterior" side, and it is usually the shortest half of the shell. In some Bivalves, however, the beaks are "reversed," and are turned towards the posterior side of the shell. The longer half of the shell, from which the umbones turn away, is called the "posterior" side, but in some cases this is equal to, or even shorter than, the anterior side. The side of the shell where the beaks are situated, and where the valves are united to one another, is called the "dorsal" side; and the opposite margin, along which the shell opens, is called the "ventral"

side or "base." The *length* of the shell is measured from its anterior to its posterior margin, and its *breadth* from the dorsal margin to the base.

At the dorsal margin the valves are united to one another, for a shorter or longer distance, along a line which is called the "hinge-line." The union is effected in most shells by means of a series of parts which interlock with one another (the "teeth"), but these are sometimes absent, when the shell is said to be "edentulous." Posterior to the umbones, in most Bivalves, is another structure passing between the valves, which is called the "ligament," and which is usually composed of two parts, either distinct or combined with one another. These two parts are known as the "external ligament" (or the ligament proper) and the "cartilage," and they constitute the agency whereby the shell is opened; but one or other of them may be absent. The ligament proper is outside the shell, and consists of a band of horny fibres, passing from one valve to the other just *behind* the beaks, in such a manner that it is put upon the stretch when the shell is closed. The cartilage, or internal ligament, is lodged between the hinge-lines of the two valves, generally in one or more "pits," or in special processes of the shell. It consists of elastic fibres placed perpendicularly between the surfaces by which it is contained, so that they are necessarily shortened and compressed when the valves are shut. To open the shell, therefore, it is simply necessary for the animal to relax the muscles which are provided for the closure of the valves, whereupon the elastic force of the ligament and cartilage is sufficient of itself to open the shell.

Generally the hinge-line is curved, but it is sometimes straight. The beaks are mostly more or less closely contiguous; but they may be removed from one another to a greater or less distance, and in some anomalous forms they are not near one another at all. In the genus *Arca* the two beaks are separated from one another by an oval or lozenge-shaped flat space or area. When teeth are present, they differ much in their form and arrangement. In many forms (fig. 554) the teeth are divisible into three sets—one group, of one or more teeth, placed immediately beneath the umbo, and known as the "cardinal teeth"; and two groups on either side of the preceding, termed the "lateral teeth." Sometimes there may be lateral teeth only; sometimes the cardinal teeth alone are present; and in some cases (*Arcidæ*) there is a row of similar and equal teeth.

While the opening of the valves of the shell of a Lamellibranch is effected by the elastic force of the ligament, the closure of the valves is effected by the contraction of one or two powerful muscles, which are known as the "adductor muscles." In the majority of Bivalves—hence termed *Dimyaria*—there are two adductor muscles,

which pass from the inner surface of one valve to that of the other, one being placed anteriorly in front of the mouth, while the other is situated posteriorly close to the termination of the intestine (fig. 555, *a* and *a'*). Moreover, among the Dimyary Bivalves the adductors present two markedly different conditions. In one group of forms—hence termed *Homomyaria*—the anterior and posterior adductors are approximately equal in size. In a second series—hence termed *Heteromyaria*—the anterior adductor is very small, and the posterior adductor is very large. Examples of this latter condition are found in the Mussels, Pearl-mussels, &c. On the other hand, in *Ostrea*, *Pecten*, and certain other Bivalves—hence called *Monomyaria*—the anterior adductor is absent, and the posterior adductor alone remains. The adductors leave distinct "muscular impressions" in the interior of the shell (fig. 556), so that it is easy to determine, by a simple inspection of the dead shell, whether a given Bivalve has been "dimyary" or "monomyary."

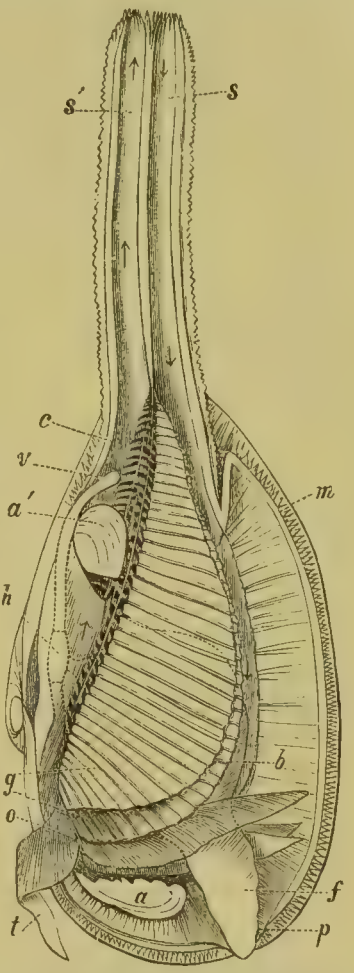


Fig. 555.—Anatomy of *Mya arenaria*. (After Woodward.) The left valve of the shell and the left mantle-lobe are removed, and half of the siphons has been cut away. *a*, Anterior adductor; *a'*, Posterior adductor; *b*, Visceral mass; *c*, Chamber of the mantle-cavity into which the anus (*v*) opens; *f*, Foot; *g*, Branchiæ; *h*, Heart; *m*, Cut ventral edge of the mantle; *o*, Mouth; *s*, Inhalant siphon; *s'*, Exhalant siphon; *t*, Labial palpi. The arrows indicate the direction of the water-currents.

Besides the scars left by the adductor muscles, or muscle, there are other impressions in the interior of the valves which are produced by the attachment of muscles. Thus, the "foot" is very commonly provided with "pedal muscles," which leave small scars in the inside of the shell. When they are well developed, the "pedal impressions" are twofold, consisting of an impression formed by the "protractor" muscle which exserts the foot, and of another, posteriorly-placed scar formed by the "retractor" muscle which withdraws the foot (fig. 556, A, *pp* and *rp*), a second retractor being sometimes inserted behind the anterior adductor.

Again, the muscular margin of the mantle is attached to the

interior of each valve along a line running at a little distance within, and parallel with, the ventral margin of the shell. In this way is formed a more or less well-marked impression in the interior of each valve, which is termed the "pallial line" (fig. 556, *m*). The form assumed by the "pallial line" differs in different Bivalves according as respiratory "siphons" are present or absent. In all those Bivalves, namely, in which the mantle-lobes are free, and in which

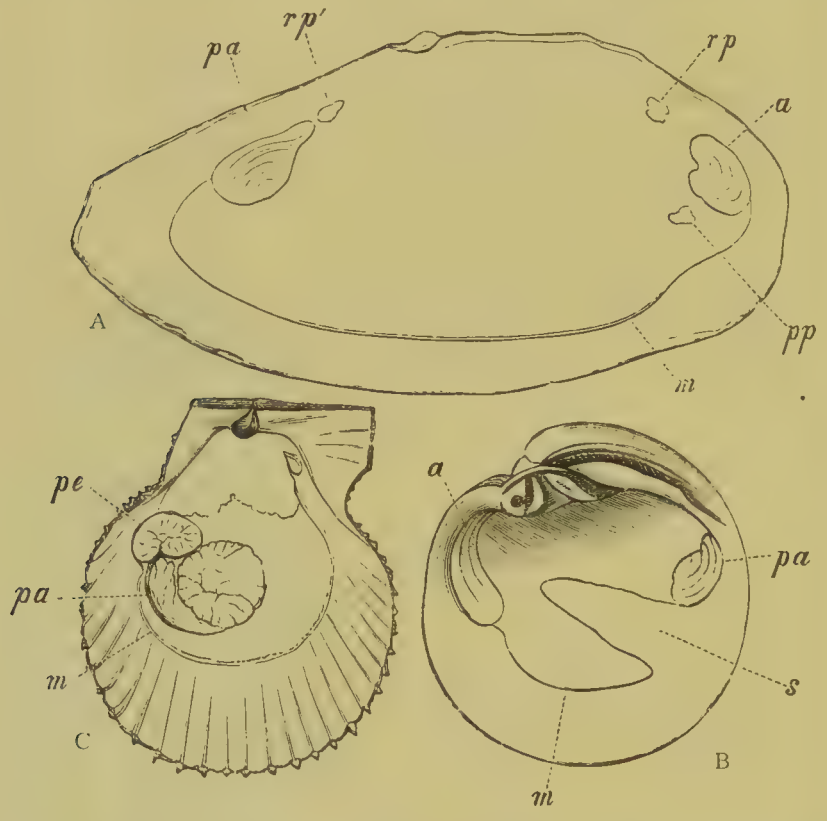


Fig. 556.—A, Interior of the left valve of *Anodonta cygnea*; B, Interior of the right valve of *Artemis exoleta* (after Woodward); C, Interior of the left valve of *Pecten varius* (after Woodward). *a*, Impression of the anterior adductor; *pa*, Impression of the posterior adductor; *m*, Pallial line; *s*, Sinus in the pallial line caused by the insertion of the retractor muscles of the siphons; *pp*, Scar of the protractor muscle of the foot; *rp*, Scar of the anterior retractor muscle of the foot; *rp'*, Scar of the posterior retractor muscle of the foot. In *Pecten varius* (C), though the shell is monomyary, the scar left by the posterior adductor (*pa*) is double, and there is a large scar (*pe*) formed by the muscular base of the foot.

there are consequently no siphons, the "pallial line" runs in an unbroken curve round the lower part of the valve (fig. 556, A, *m*). The pallial line is similarly unbroken in those Bivalves which possess short siphons, but which do not possess a specially developed "retractor muscle" for the withdrawal of the siphons within the shell. The name of *Integropallialia* is given to all such Bivalves as the above, in which the pallial line is "entire," or unindented, and there

are either no siphons or but short ones. On the other hand, in those Bivalves which have long respiratory siphons there exists on each side a specially developed "retractor muscle," the function of which is to withdraw the siphons within the shell. The insertion of this siphonal retractor causes an indentation in the pallial line posteriorly (fig. 556, B, *s*), the depth of this depending upon the size of the siphonal muscles. In all those Bivalves, therefore, which possess retractile siphons, the pallial line is deflected posteriorly into a larger or smaller "pallial sinus" or "siphonal impression;" and those Bivalves in which this sinus exists are grouped together under the name of *Sinupallialia*.

There is no distinctly differentiated head in any of the Lamellibranchs (hence the name of "Acephalous Molluscs" commonly given to the class), and the mouth is simply placed at the anterior end of the body. It is furnished with ciliated, leaf-like, membranous processes, or "labial palpi" (fig. 555, *t*), which are two or four in number, and serve to conduct the in-going water-currents to the mouth. The mouth is not furnished with any arrangement of teeth, and the animal lives upon the microscopic particles of nutrient matter brought to the mouth by the in-going currents of water, which are kept in movement by the action of the cilia covering the gills. These organs (fig. 555, *g*) are leaf-like, and are attached by their bases to the sides of the body, their free ends depending into the mantle-cavity. Most Bivalves have two of these lamellar branchiæ on each side of the body, but the external pair may be wanting.

As has been already mentioned, the arrangements for the admission of water to the gills, and its expulsion again from the mantle-cavity, are essentially the same in all Bivalves. In almost all cases the in-going current of water enters the pallial chamber posteriorly and ventrally, while the out-going current escapes posteriorly and dorsally. In those Bivalves which have free mantle-lobes ("Asiphonate Bivalves"), the apertures for the water-currents are simply produced by the apposition of the hinder edges of the mantle-lobes to each other. On the other hand, in those Bivalves which have the mantle-lobes united ("Siphonate Bivalves," fig. 555), the margins of the "inhalant" and "exhalant" apertures are drawn out or extended into longer or shorter muscular tubes or "siphons." The siphons may be separate, or they may be united to one another along one side, and they can usually be partially or entirely retracted within the shell by means of special muscles, called the "retractor muscles of the siphons." These siphons are more specially characteristic of those Lamellibranchs which spend their existence buried in the sand, protruding their respiratory tubes in order to obtain water, and with it such nutrient particles as the water may contain. As has been

previously seen, the presence or absence of retractile siphons can be readily determined merely by inspection of the dead shell.

The *Lamellibranchiata* are wholly aquatic, living in either salt or fresh water, and their habits are very various. Some, such as the Oyster (*Ostrea*), and the Scallop (*Pecten*), habitually lie on one side, the lower valve being the deepest, and the foot being wanting, or rudimentary. The former is fixed by the substance of the valve, but the latter swims by rapidly opening and closing the shell. Others, such as the Mussel (*Mytilus*) and the *Pinna*, are attached to some foreign object by a "byssus." Others are fixed to some solid body by the substance of one of the valves. Many, such as the *Mya*, spend their existence sunk in the sand of the sea-shore or in the mud of estuaries. Others, as the *Pholades* and *Lithodomi*, bore holes in rock or wood, in which they live. Finally, many are permanently free and locomotive.

The *Lamellibranchiata* have often been divided into two primary sections, according as "siphons" are or are not developed. In one of these sections—*Asiphonida*—the mantle-lobes are free, and there are no respiratory siphons, so that the pallial line is simple and is not indented. In the other great section—*Siphonida*—the mantle-lobes are more or less united, and respiratory siphons are present. In certain groups of the Siphonate Bivalves the siphons are short, without specially developed retractor-muscles, and the pallial line is therefore simple, the name of *Integropallialia* being given to such forms. On the other hand, in many types of the Siphonate Bivalves —hence termed *Sinupallialia*—there are long siphons, the greatly developed retractor-muscles of which are attached to an indentation or bay in the pallial line. This classification is doubtfully natural, and is largely inapplicable to fossil forms; for which reasons the arrangement adopted by Dr Paul Fischer in his 'Manuel de Conchyliologie' has, in the main, been here followed in preference. Owing, however, to the great importance in the study of the fossil Bivalves of the various internal markings of the shell, it may be of use here to indicate generally the principal groups of Lamellibranchs which agree with one another in the general nature of the impressions left by the pallial line and adductors; a guide being thus given to the families amongst which the affinities of a given fossil shell must be sought. From this point of view, the Bivalves fall into the four following sections, the families of which, though often allied, have no necessary zoological relationship with one another :—

(1.) The following families of *Lamellibranchiata* are "monomyary," and have an "entire" pallial line, no siphons being developed—viz., the *Ostreidæ*, *Anomiidæ*, *Spondylidæ*, *Limidæ*, and *Pectinidæ*. This group of families corresponds with the *Monomyaria* of some writers.

(2.) The following families are "heteromyary," and have no siphons, the

pallial line being "entire"—viz., the *Aviculidæ* and *Mytilidæ* (= the *Heteromyaria* of Bronn).

(3.) The following families are "homomyary," and have an "entire" pallial line, the animal being in some cases devoid of siphons, while in other cases short, non-retractile siphons are present—viz., the *Arcidæ*, *Nuculidæ*, *Modiolopsidæ*, *Trigoniidæ*, *Unionidæ*, *Cardinidæ*, *Carditidæ*, *Grammysiidæ*, *Astartidæ*, *Crassatellidæ*, *Erycinidæ*, *Galeommidæ*, *Tridacnidæ*, *Cardiidæ*, *Lunulicardiidæ*, *Chamidæ*, *Rudistæ*, *Megalodontidæ*, *Cyprinidæ*, *Ungulinidæ*, *Unicardiidæ*, and *Tancrediidæ*.

(4.) The following families are "homomyary," and are provided with retractile siphons, the pallial line thus becoming "sinuated"—viz., the *Veneridæ*, *Donacidæ*, *Psammobiidæ*, *Solenidæ*, *Mactridæ*, *Myidæ*, *Glycimeridæ*, *Gastrochænidæ*, *Pholadidæ*, *Teredinidæ*, *Lucinidæ*, *Tellinidæ*, *Scrobiculariidæ*, *Solemyidæ*, *Arcomyidæ*, *Anatinidæ*, *Præcardiidæ* (?), *Pholadomyidæ*, and *Clavagellidæ*.

As regards their general *distribution in time*, the Lamellibranchs are a very ancient group, the earliest representatives of the class (*Glyptarca*, &c.) being found in the Upper Cambrian rocks. Upon the whole, the Asiphonate Bivalves are more characteristically Palæozoic, while those in which the mantle-lobes are united and there are respiratory siphons, are principally found in the Secondary and Tertiary rocks. One of the principal Palæozoic groups is that of the *Aviculidæ*, while the *Mytilidæ* are also largely represented. Monomyary types appear in the later portion of the Palæozoic period, numerous forms (*Aviculopecten*, &c.) allied to the recent Scallops occurring in the Carboniferous rocks. With the commencement of the Secondary period, in the Trias, many old types disappear, and new ones take their places. Monomyary Bivalves are now numerous, but among the Dimyary forms the Asiphonate families still predominate. The forms with long retractile siphons (*Sinupallialia*) begin with a few types in the Trias, and gradually become more numerous as we pass upwards. The *Veneridæ*, which are perhaps the most highly organised of the groups of the Lamellibranchs, appear for the first time in the Jurassic rocks, and increasing in the Tertiaries, have culminated in the Recent period. The singular group of the *Rudistæ* is exclusively confined to the Cretaceous period.

CHAPTER XXXVI.

LAMELLIBRANCHIATA—continued.

DIVISIONS OF LAMELLIBRANCHIATA.

VARIOUS attempts have been made to divide the *Lamellibranchiata* into sections equivalent to the "orders" of the higher animals, but, so far, little success has attended these efforts, and no arrangement which has hitherto been proposed can be regarded as thoroughly satisfactory, more especially from a palæontological point of view. In what follows, the *Lamellibranchiata* are divided into a number of sections, which it is convenient to speak of as so many "orders," though it cannot be asserted that they have a value equivalent to the divisions known by this title among Vertebrate animals. As regards these primary sections, Dr Paul Fischer has been followed, and under each section will be given the characters and geological range of the more important families included in it.

ORDER I. OSTREACEA.

In this order the mantle-lobes are completely free; a single adductor muscle (the posterior) is alone present, the animal being thus "monomyary"; there are two branchiæ on each side of the body; and the foot is wanting, or is present in a rudimentary form and secretes a "byssus." The shell is inequivalve; the hinge is edentulous; the ligament is internal; and the pallial line is "entire," and sometimes not distinct. This order includes the two families of the *Ostreidæ* and *Anomiidæ*.

FAMILY 1. OSTREIDÆ.—In this family the shell is generally inequivalve and fixed to foreign bodies by the substance of the left valve, but is in other cases free; the beaks are subcentral, or, in many cases, twisted; the ligament is internal, and is lodged in a triangular cartilage-pit; the single muscular impression is subcentral, or excentric and posterior; the pallial line is not distinct; and the

shell-structure is laminated. This family is exclusively confined to salt water, and comprises the Oysters. Numerous Secondary and Tertiary representatives of the family are known, but the few Palæozoic types which have been referred here are probably really of a different nature.

The principal genus included in the *Ostreidæ*, as here understood, is *Ostrea* itself, the essential characters of which are those of the

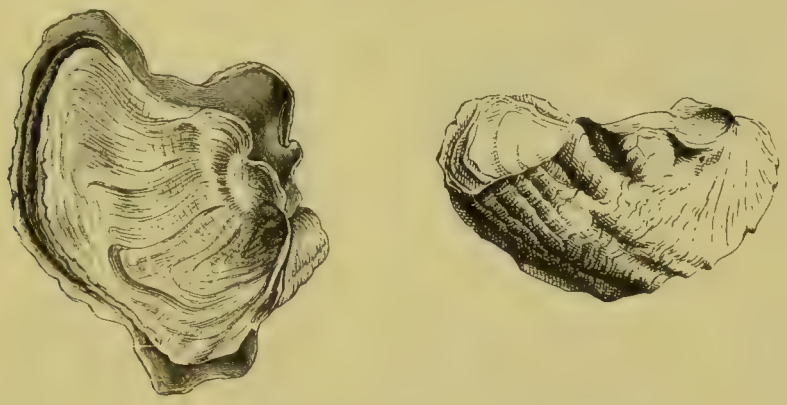


Fig. 557.—*Ostrea* (*Exogyra*) *Couloni*. Lower Greensand.

family itself. The shell described by De Koninck from the Carboniferous Limestone under the name of *Ostrea nobilissima* has generally been quoted as the oldest known type of the genus *Ostrea*, but it is referred by Fischer to the genus *Pachypteria* (*? Spondylidæ*). In the Secondary and Tertiary rocks, however, we meet with a vast



Fig. 558.—*Ostrea* (*Alectryonia*) *Marshii*. Oxford Clay (Middle Oolites).



Fig. 559.—*Gryphæa incurva*. Lias.

number of fossil Oysters, which have commonly been distributed among several more or less well-marked sections of the genus, of which the following are the most important. In the typical forms of the genus (*Ostrea* proper) the valves are pretty nearly of the same length, the lip of the right valve is not serrated, and the external

surface is marked with concentrically-disposed foliaceous ridges or with roughly radial ribs. The umbo is not incurved, and below it is a transversely striated ligamental pit. The Edible Oyster (*O. edulis*) is a familiar example of this section of the genus, and essentially similar forms are known to have existed in the Jurassic rocks. In the sub-genus *Alectryonia* (fig. 558) both the valves are strongly ribbed or folded, the edges of the valves being thus indented in a

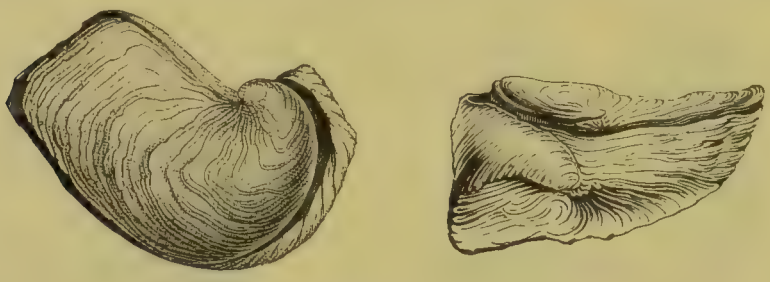


Fig. 560.—*Exogyra aquila.* Lower Greensand.

zigzag manner; while the adductor impression is placed far back. Forms of this type began to exist as early as the Trias, and the recent *O. crista-galli* is a familiar example of a now living form of the group.

In the sub-genus *Gryphæa* (fig. 559), the two valves are of unequal length, the left valve fixed in early life, but often becoming free in the adult condition, while its beak is prolonged and incurved, being bent either forwards or backwards. The right valve, on the other hand, is small in size, and is flat or concave in shape, looking like a kind of operculum to the left valve. The species of *Gryphæa*

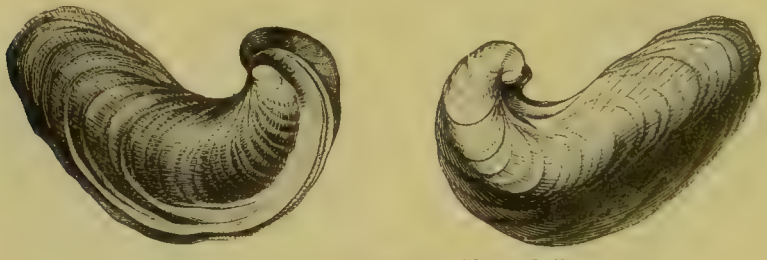


Fig. 561.—*Exogyra virgula.* Upper Oolites.

are pre-eminently Jurassic and Cretaceous, but a few Tertiary and Recent forms of the group are known.

In the sub-genus *Exogyra*, again, the shell is very inequivalve (figs. 557, 560, and 561), and is fixed by the substance of the thick and concave left valve, the right valve being flat and resembling an "operculum" in form. The beaks of both valves are rolled up, being "reversed"—that is to say, turned towards the posterior side

of the shell—and the ligamental area is oblique and narrow. The species of *Exogyra* are abundant in the Jurassic and Cretaceous deposits.

The name of *Pernostrea* has been proposed by Munier-Chalmas for certain Jurassic Oysters which differ from *Ostrea* proper chiefly in having the ligament contained in from four to eight transverse grooves or pits (as in *Perna*).

Family 2. Anomiidæ.—In this family the shell is inequivalve, and is fixed to foreign objects, either in early life or permanently, by a byssus, which traverses a notch or foramen in the right valve, and is ordinarily calcified at its termination. The muscles of the byssus leave one or more impressions on the interior of the left valve. There is an internal ligament; the hinge is edentulous; the pallial line is simple; and the shell exhibits a laminated structure. The range of the family is from the Devonian to the present day, and the chief genera are *Anomia* and *Placuna*.

In the genus *Anomia* (fig. 562) the shell is suborbicular and ostreiform, the left or upper valve being convex, while the right or under valve is flat or concave. In the margin of the right valve, near

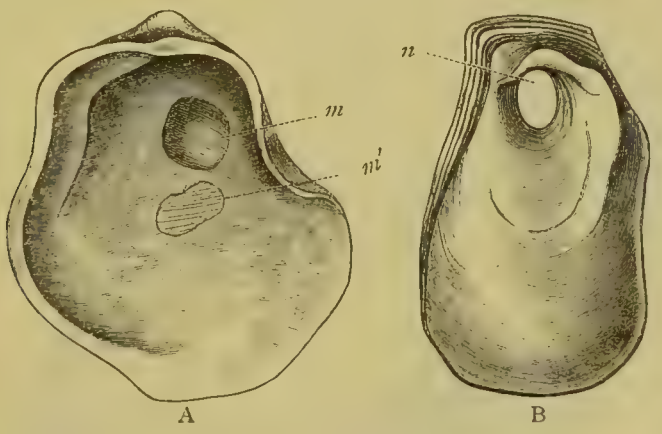


Fig. 562.—*Anomia Casanovei*, from the Eocene Tertiary, enlarged. A, Interior of the left valve; B, Interior of the right valve: *n*, Foramen for the passage of the byssus; *m*, Impressions left by the muscles of the byssus; *m'*, Adductor impression. (After Hoernes.)

the hinge, is a deep notch or sinus, which in process of growth may be converted into a complete foramen, and which serves to transmit the byssus, by means of which the shell is attached to foreign bodies. The end of the byssus is calcified, and it forms a solid plug which fills up the notch or foramen in the valve. The interior of the right valve shows only the impression of the single adductor, but the interior of the left valve exhibits in addition one to three scars produced by the muscles of the byssus. All the living forms of *Anomia* are marine, and the genus is represented in past time by numerous

Tertiary species, and, more rarely, by Cretaceous and Jurassic types. The *Limanomia* of the Devonian rocks is, however, very closely related to *Anomia* proper, from which it differs in the pointed shape and radial striation of the valves, and in the fact that the byssal foramen is trigonal in form.

The extinct genus *Placunopsis*, ranging from the Carboniferous Limestone to the Jurassic, resembles *Anomia* in many respects, but the right valve is not perforated; the ligament is lodged in a transverse, submarginal groove; and the adductor impression is large and subcentral. The genus *Placuna* comprises flattened and cake-like, orbicular shells, which are unattached to foreign bodies. The elastic ligament is supported by two diverging ridges in the right valve, with corresponding grooves in the left valve. The typical forms of the genus are recent, but types of no more than sub-generic value occur in the Tertiary rocks. The Jurassic genus *Hypotrema* is intermediate between *Anomia* and *Placuna*, since it possesses a byssal foramen which is completely closed in the adult.

Order II. Pectinacea.

In this order, the mantle-lobes are completely free; there is a single adductor only; there are no siphons; there are two branchiæ on each side of the body; and the foot is rudimentary and often byssiferous. The shell-structure is tubulated or lamellated, but without a proper prismatic layer. The shell is inequivalve or sub-equivalve; the ligament is lodged in a pit between the beaks; the hinge is generally toothed; and the pallial line is entire. This order contains the three principal families of the *Spondylidæ*, *Limidæ*, and *Pectinidæ*, all the recent forms of which are marine.

Family 1. Spondylidæ.—In this family the shell is inequivalve,



Fig. 563.—*Spondylus spinosus*. Chalk.

and is attached to foreign bodies by the beak of the right valve, which is larger than the left. The hinge of each valve has two teeth, between which is the cartilage-pit. The adductor impression

is subcentral. The two principal genera of this family are *Spondylus* and *Plicatula*.

The genus *Spondylus*, comprising the "Thorny Oysters," has an equivalve shell, the right valve being the deepest, and serving for the attachment of the shell to foreign bodies (fig. 563). The beaks are separated and are eared, and the shell is covered with spines, foliaceous expansions, or ribs radiating from the beak. The lower valve has a triangular hinge-area, and there are two teeth in each valve. The *Spondyli* seem to have commenced in the Jurassic period (? Trias), are abundant in the Cretaceous, and have continued through the Tertiary period to the present day.



Fig. 564.—*Plicatula placunea*. Lower Greensand.

The genus *Plicatula* (fig. 564) approaches *Spondylus* nearly in having an inequivalve shell, which is attached by the right valve, and by having two hinge-teeth in each valve. The shell, however, is rarely eared, the hinge-area is obscure, and the valves are not spiny, though they may be plaited. The *Plicatulæ* extend from the Trias to the present day, and they abound to such an extent in parts of the Lower Greensand (Cretaceous), as to have given rise to the name of "Argile à Plicatules" applied to the beds in question. Lastly, the genus *Terquemia*, of the Triassic and Liassic rocks, resembles *Spondylus* in many respects, but is at once distinguished by the fact that the hinge is edentulous. In this respect the genus resembles the Oysters, from which it is separated by the fact that the shell is attached by the *right* valve, and not by the left. Fischer also includes in this family, with doubt, the Carboniferous genus *Pachypteria*.

Family 2. Limidæ.—The shell in this family is auriculate, and equivalve or nearly so, and it may be free or may be attached by a byssus, which passes out by a sinuosity in the right valve or by a notch below the anterior ears. The beaks are pointed and straight, and a portion of the hinge-area and ligament is left externally visible; while hinge-teeth may be wanting or present. The earliest types of the family appear in the Carboniferous rocks; there are numerous Secondary and Tertiary forms; and the present seas contain a limited number of existing species.

In the genus *Lima* or *Radula* the shell is equivalve and free, and the beaks are separated from one another and eared (fig. 565). The surface is generally adorned with radiating ribs or striæ, and there is a median cartilage-pit, and a triangular hinge-area. The genus (including *Plagiostoma*) appears to occur in the Carboniferous, is abundantly represented in the Triassic, Jurassic, Cretaceous, and Tertiary rocks, and exists in diminished numbers at the present day. *Limea*, ranging from the Trias to the Recent period, differs from *Lima* principally in having the hinge-line closely toothed.

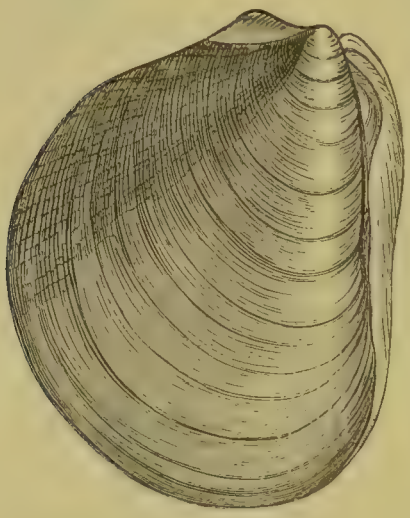


Fig. 565.—*Lima* (*Plagiostoma*) *gigantea*. Lias.

Family 3. Pectinidæ.—In this family the foot is tongue-shaped and byssiferous; the margins of the mantle-lobes carry ocelli; and the adductor impression is a little excentric. The shell is sub-equivalve or equivalve, nearly equilateral, auriculate, free or occasionally attached by the right valve. Generally there is a notch under the ear of the right valve for the passage

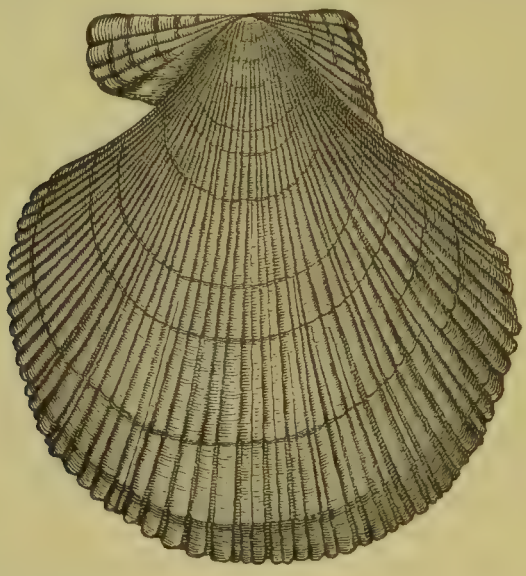


Fig. 566.—*Pecten Islandicus*, left valve. Post-Tertiary and Recent.

of the byssus; and the cartilage-pit is internal, of triangular shape, and placed between the beaks, being rarely broken up into detached pits. All the members of this family are marine, its earliest forms

appearing in the Devonian rocks, while numerous living types exist.

The genus *Hinnites* comprises a number of forms in which the shell is free when young, but becomes in adult life attached by the right valve, the shell becoming at the same time thick and irregular. The left valve is free, and the hinge-line is edentulous. Numerous fossil forms of *Hinnites* are known, the earliest appearing in the Trias, and the genus still survives.

In the genus *Pecten*, comprising the Scallops, the shell (fig. 566) rests upon the right valve, and the beaks are furnished with ears. The anterior ears are the largest and most prominent, and the shell is generally furnished with ribs radiating from the umbos. There is a single, median, triangular cartilage-pit. The right valve is the deepest, and is notched for the byssus below the anterior ear. Using the name *Pecten* in its modern and restricted signification, it is probable that all the Palæozoic shells so named are really referable to allied genera (*Aviculopecten* and *Pernopecten* more especially). The genus, however, is largely represented both in the Secondary and Tertiary deposits, and exists under numerous and varied forms at the present day.

The name of *Entolium* has been given to forms of *Pecten* in which the shell is smooth, the hinge-line is rendered angular by the outward extension of the ears, and there is no byssal notch under the anterior ear of the right valve. Numerous forms of this type occur from the Jurassic onwards; but the Palæozoic shells which have been placed here are probably referable to allied genera, such as *Pernopecten*. In the genus *Pernopecten*, of the Devonian and Carboniferous rocks, are comprised ancient types of Scallops, with small, nearly equal, ears, the central triangular cartilage-pit being flanked by a row of smaller pits on each side (thus approaching *Perna*), and the surface being nearly or quite devoid of radiating ridges. The genus *Crenipecten*, with a similar geological range to *Pernopecten*, has the hinge furnished with a row of small cartilage-pits along its entire length, no central pit being present.

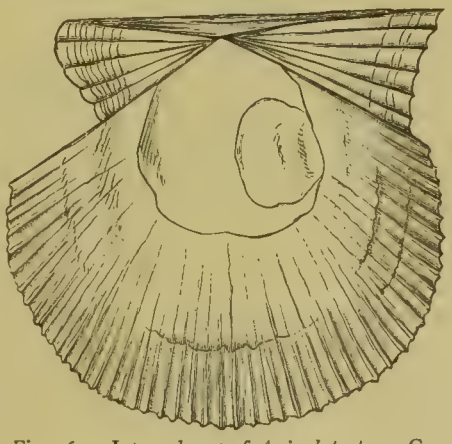


Fig. 567.—Internal cast of *Aviculopecten*. Carboniferous. (After M'Coy.)

Of the Palæozoic types of the *Pectinidæ*, the most important is the large and widely distributed genus *Aviculopecten*, which, as its name implies, affords a transitional link between the present family

and that of the *Aviculidæ*. The shell in this genus (fig. 567) has the general form and aspect of that of *Pecten* itself; but the anterior ear is flattened, and *smaller than the posterior one*. There is a byssal notch beneath the anterior ear; but there is no median cartilage-pit, and the ligament is confined to a narrow facet along the hinge-margin. The muscular impression and pallial line are as in *Pecten*. The hinge-line is usually shorter than the transverse diameter of the shell, and the surface is generally adorned with radiating ribs. The species of *Aviculopecten* are distributed between the Devonian and Permian, but they are most characteristic of the Carboniferous rocks, in which they are extremely abundant. In the absence of a median cartilage-pit, and the lodgment of the ligament in a groove along the hinge-line, the genus approaches the *Aviculidæ*, but its shell is stated by Meek to have the corrugated and laminated structure of *Pecten*, and not the prismatic structure of the former. The genus *Streblopteria* of the Carboniferous and Permian rocks comprises forms which agree with *Aviculopecten* in having the ligament in a groove along the margin of the ears; but the posterior ear is hardly marked off from the hinder margin of the shell, and an oblique posterior cardinal tooth is present.

Order III. Mytilacea

(= *Heteromyaria*, Bronn).

In this order the mantle-lobes are free, the pallial line is entire, and there are usually two adductor muscles. (In the Tertiary genus *Dreissenomya* the pallial line is sinuated; while the recent genus *Prasina* is monomyary.) The anterior adductor is small; the posterior is of large size. The foot is tongue-shaped and usually byssiferous. The shell possesses an external, often largely developed, prismatic layer, and may be inequivalve or equivalve. The ligament is generally contained in several marginal grooves or in an oblique furrow; and the hinge may or may not be provided with teeth. The two principal families contained in this order are the *Aviculidæ* and *Mytilidæ*, and the recent forms are in part marine, and in part inhabitants of fresh waters.

Family 1. Aviculidæ.—In this family the mantle-lobes are free, the foot is small and byssiferous, and the shell-structure consists of an internal nacreous layer and an external prismatic layer. The anterior adductor [1] is small, and leaves its impression at the base of

[1] The muscle which is here spoken of as the "anterior adductor" is sometimes regarded as, in some cases, being really the anterior retractor of the foot. On this view, there is no anterior adductor muscle in some of the most typical forms of the *Aviculidæ*, the animal being monomyary.

the anterior ear; the posterior adductor impression is large and subcentral. The shell is inequivalve or subequivalve, oblique, with a straight hinge-line, and furnished on one or both sides with wing-like expansions or ears. Under the anterior ear of the right valve is a notch or aperture for the transmission of the byssus. The family of the *Aviculidæ* is a very large one, and has a most extensive development in past time, beginning under various types in the Ordovician rocks, and being continued thereafter to the present day. The principal forms included in this family may be briefly considered under the following groups :—

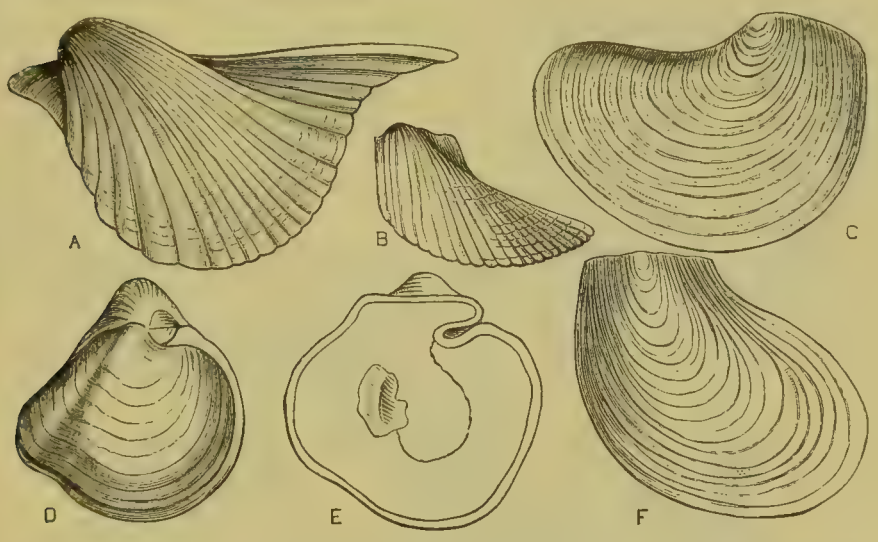


Fig. 568.—Types of *Aviculidæ*. A, *Avicula Cottaldina*—Cretaceous; B, *Avicula contorta*—Upper Trias; C, *Vulsella falcata*—Eocene; D, *Pseudomonotis speluncaria*—Permian; E, Interior of the shell of the same, showing the adductor impression and pallial line; F, *Posidonomya Becheri*—Lower Carboniferous.

Firstly, we have the great group of shells, of which *Avicula* itself (fig. 568, A and B) is the type. In this genus the shell is oblique and inequivalve, the right valve being smaller and less convex than the left. The right valve has a byssal notch under the anterior ear, and the hinge has one or two cardinal teeth, sometimes with an elongated posterior tooth. The ligament is partly external, partly contained internally in a deep groove. The species of *Avicula* range from the Ordovician period to the present day, numerous forms of this genus occurring in the Secondary and Tertiary rocks.

More or less closely allied to *Avicula* are the Palæozoic genera *Leiopteria* (Devonian and Carboniferous), *Monopteria* (Carboniferous), *Pteronites* (Devonian and Carboniferous), *Limoptera* (Devonian), and *Eopteria* (Ordovician). Also related to *Avicula* is the genus *Pseudomonotis* (*Eumicrotis*, Meek), in which the shell is but slightly oblique, and is inequivalve,

the left valve convex, with a prominent beak. The hinge is nearly or quite toothless, and the anterior ear is small or undeveloped, while a deep byssal notch in front is present (fig. 568, D and E). The earliest forms of *Pseudomonotis* are found in the Devonian rocks, but the genus attains its maximum in the Triassic and Jurassic rocks. A well-known species from the Permian rocks of Europe is *P. speluncaria* (fig. 568, D). In the singular Triassic genus *Cassianella* (fig. 570, D and E) the shell is thick and very inequivalve, the right valve being flat or concave, while the left is strongly convex. The hinge-line is straight, with few teeth, the ligament being lodged in a triangular groove behind the beaks; a byssal notch is absent; and the shell is eared.

Another, but limited, group is that represented by *Vulsella* and *Malleus*, together with some Secondary and Tertiary forms of small importance, characterised by the common feature that the ligament is lodged in a single pit extending from the beak internally. In *Vulsella* (fig. 568, C) the shell is nearly equivalve and earless, the hinge being toothless, and a byssal notch being absent. The genus dates from the Eocene Tertiary, and still survives. On the other

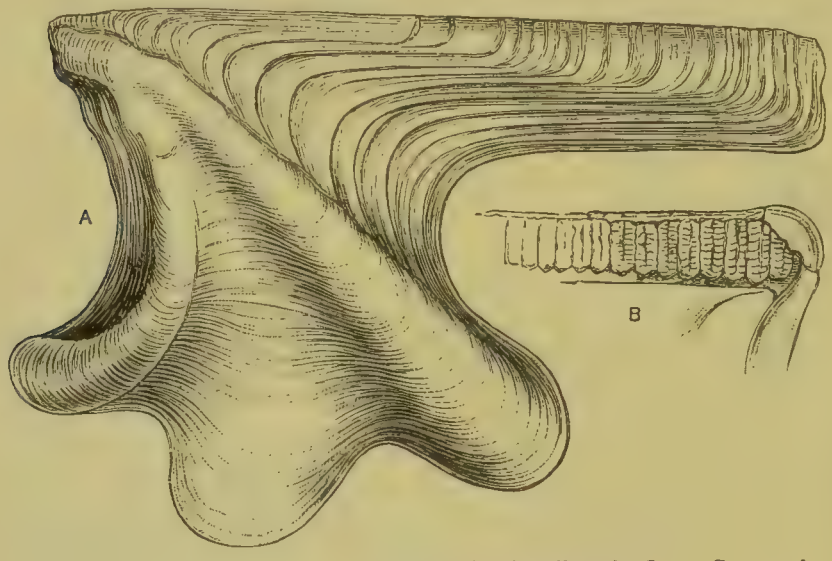


Fig. 569.—*Perna Mulleti* (A), and a portion of its hinge-line (B). Lower Greensand.

hand, the "Hammer-oysters" (*Malleus*) are not known in the fossil state, and are distinguished by their very long ears and central beaks.

A third, much more important, group of the *Aviculidæ* is that represented by *Perna* and its allies, all of which have a straight hinge-line, crossed by numerous transverse furrows for the lodgment of the ligament. In *Perna* (or *Melina*) itself (fig. 569) the shell varies in form, but there is generally a long posterior ear; there are numerous close-set cartilage-pits, and the right valve has a byssal

notch. The genus begins in the Trias, is well represented in the later Secondary and Tertiary deposits, and still survives under a few forms. A large and well-known species is the *Perna Mulleti* of the Neocomian rocks. Allied to the preceding is the genus *Gervillia* (fig. 570, A), in which the shell is elongated and very oblique, with a broad and wing-like posterior ear. The hinge-line is furnished with numerous cartilage-pits (fig. 570, B), and the anterior ear is comparatively small, while the beaks are nearly or quite terminal in position. The species of *Gervillia* abound in the Triassic, Jurassic, and Cretaceous rocks, and a single species of the

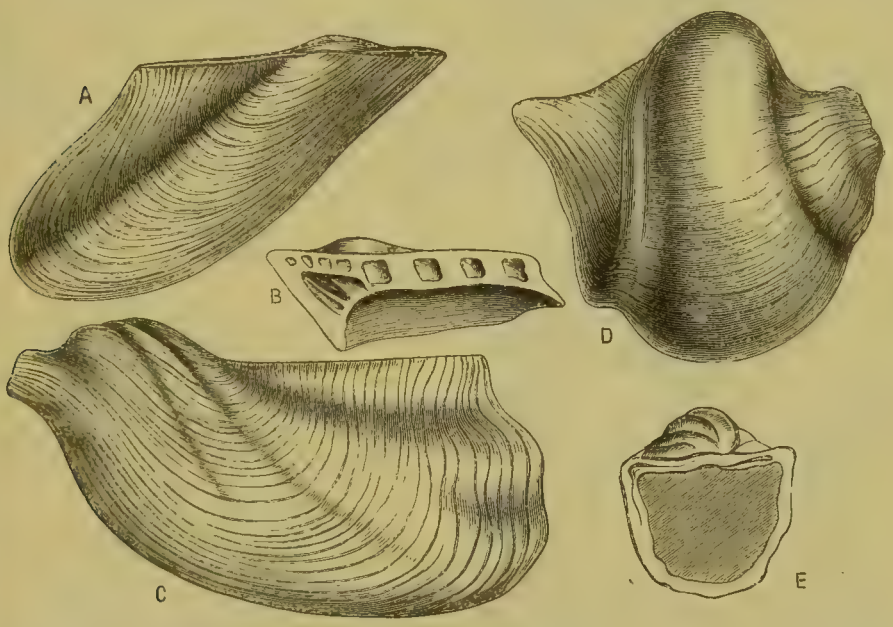


Fig. 570.—Types of *Aviculidæ*. A, *Gervillia Hartmanni*—Lias; B, Part of hinge of the same, enlarged; C, *Hoërnesia Joannis-Austriæ*, slightly enlarged—Trias; D and E, *Cassianella gryphæata*, of different ages—Trias. (After Münster and Laube.)

genus is found in the Eocene rocks. In the Trias are found various forms of the closely allied *Hoërnesia* (fig. 570, C), in which the left valve is greatly inflated, with a strongly incurved beak, while the hinge-line is crenulated, and a single strong tooth exists in both valves. *Bakewellia*, of the Permian, resembles *Gervillia* in general form, but the hinge is provided with anterior and posterior teeth, and the cartilage-pits are few in number. The Devonian genus *Actinodesma* is probably a still older relative of *Gervillia*.

Nearly related to both *Gervillia* and *Perna* is the important and widely-distributed genus *Inoceramus* (figs. 571, 572), which is entirely confined to the Secondary period, and is mainly characteristic of the Cretaceous series. The shells of this genus are inequivalve, with

radiating ribs or concentric furrows, and with prominent beaks. The shell is earless, and the hinge-line is long and straight, with numerous cartilage-pits. Some of the *Inocerami* attain a length of

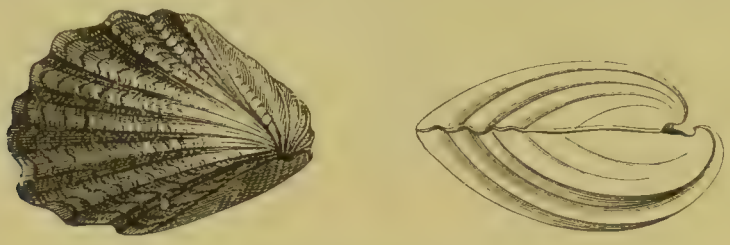


Fig. 571.—*Inoceramus sulcatus.* Gault (Cretaceous).

two or three feet, and fragments of them are often found perforated by boring sponges. The shell in the *Inocerami* consists of a thin internal nacreous layer, with a generally very thick outer prismatic



Fig. 572.—*Inoceramus problematicus.* Chalk.

stratum, but either the internal or the external layer may be destroyed in the process of fossilisation.

The Jurassic and Cretaceous genus *Aucella* (fig. 573) is related to the preceding, but may be considered as the type of a separate group of the *Aviculidæ*. In this genus, the shell (fig. 573) is very inequivalve, the left valve being convex and the right valve flat, and the beaks of both valves being inflated and incurved. The ears are imperfectly developed; the surface is concentrically striated; the ligament is external and linear; and the hinge is hardly or not at all toothed. The Carboniferous genera, *Rutotia*, *Posidoniella*, and *Aphanaia*, and the Triassic genus *Rhynchopterus*, are placed by Fischer in the same group with *Aucella*.

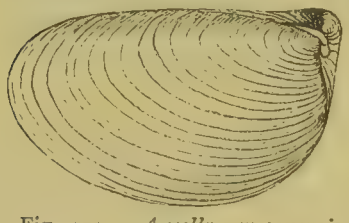


Fig. 573.—*Aucella mosquensis*, Upper Jurassic, Russia. (After Zittel.)

The genus *Monotis* is the type of another group of the *Aviculidæ*, in which the shell is equivalve, compressed, with small beaks, the ears more or less confluent with the shell, the hinge without teeth, and the ligament linear. *Monotis* itself is confined to the Trias, occurring in rocks of this age in both the Old World and the New. Very closely related to the preceding are the Triassic genera *Dac-*

nella (fig. 574) and *Halobia*, in which are comprised flat, equivalve, radiately-striated shells, more or less markedly inequilateral in shape, with a straight hinge-line, without a ligamental pit or teeth, and with no ears. Also belonging to this group is the remarkable genus *Posidonomya* (=*Posidonia*), in which the shell (fig. 568, F) is thin, concentrically striated, with a straight hinge-line, destitute of hinge-teeth, and without developed ears. The species of *Posidonomya* range from the Silurian to the Jurassic rocks, and have a general resemblance in shape to specimens of *Estheria*. The species of this genus commonly occur gregariously, and particular species are commonly characteristic of particular horizons.

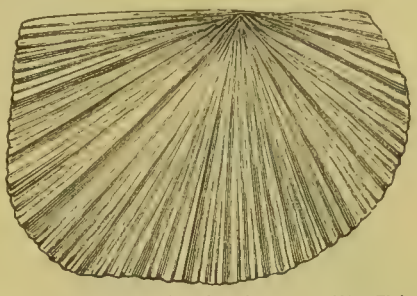


Fig. 574.—*Daonella* (*Halobia*) *Lommelli*. Trias.

The important Palæozoic genus *Pterinea* is the type of another group of the *Aviculidæ*, in which the shell (figs. 575, 576) is equi-

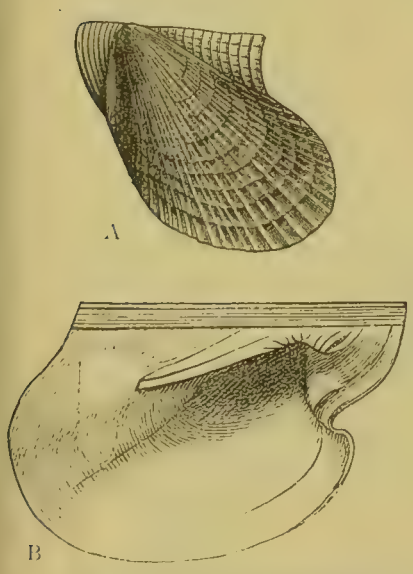


Fig. 575.—A, *Pterinea subfalcata*, Silurian. (After M'Coy.) B, Interior of the left valve of *Pterinea lævis*, Devonian. (After Zittel.)



Fig. 576.—*Pterinea* (*Avicula*) *demissa*. Ordovician rocks (Hudson River group) of North America.

valve, inequilateral, and winged, with a byssal notch below the anterior ear. The hinge has two or more cardinal teeth, with oblique lateral teeth, and there is a large, longitudinally-striated ligamental area for the reception of the internal ligament. The

small impression of the anterior adductor is placed below the anterior ear, and the surface is radiately striated. The species of *Pterinea* have a wide distribution in the Ordovician, Silurian, Devonian, and Carboniferous rocks. The Devonian genus *Glyptodesma* is allied to *Pterinea*, but the ligament is external, and the hinge has two strong lateral teeth, together with numerous irregular transverse plications along its margin.



Fig. 577.—*Ambonychia radiata.* Ordovician.

The genus *Ambonychia* (fig. 577) is the type of another group of the *Aviculidæ*, and is widely distributed in the Palæozoic rocks, ranging from the Ordovician to the Carboniferous. In this genus the shell (fig. 577) is equivalve and very inequilateral, the beaks being pointed, and placed at the anterior end of the long straight hinge-line. The ligament is internal, and is lodged in longitudinal grooves running parallel with the cardinal margin. There is no anterior ear, but a wide byssal aperture is present, while the posterior ear is broad and aliform. The Devonian genera *Mytilarca* and *Gosseletia* may be placed in the neighbourhood of *Ambonychia*.

A transition between the *Aviculidæ* and the *Mytilidæ* is effected

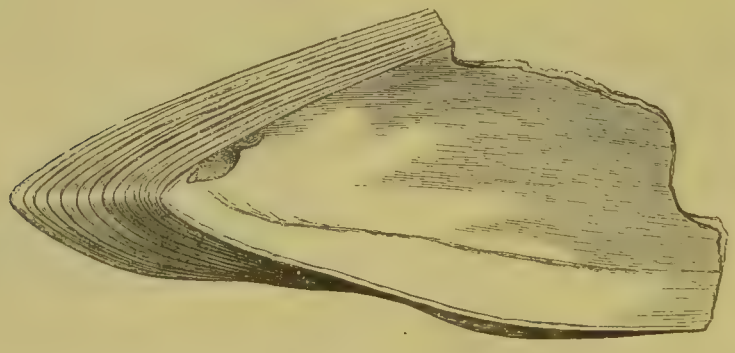


Fig. 578.—*Myalina crassa*, interior of a broken right valve, showing the hinge. Carboniferous Limestone. (Original.)

by the remarkable genus *Myalina* (fig. 578), in which the shell is inequivalve, and mussel-shaped, with terminal beaks, and a flat and thickened cardinal area marked with longitudinal cartilage-grooves, and sometimes with the umbones septate. The genus *Myalina* is

stated to range from the Silurian to the Permian, but it is principally characteristic of the Carboniferous and Permian rocks. Though the shell of *Myalina* resembles that of the *Mytilidæ* in form, the shell-structure agrees with that of the *Aviculidæ* in the presence of a well-developed external prismatic layer.

We pass naturally from the *Aviculidæ* to the *Mytilidæ* through the genus *Pinna* and its allies, which have often been regarded as constituting a special family (*Pinnidæ*). In *Pinna*, the type-genus

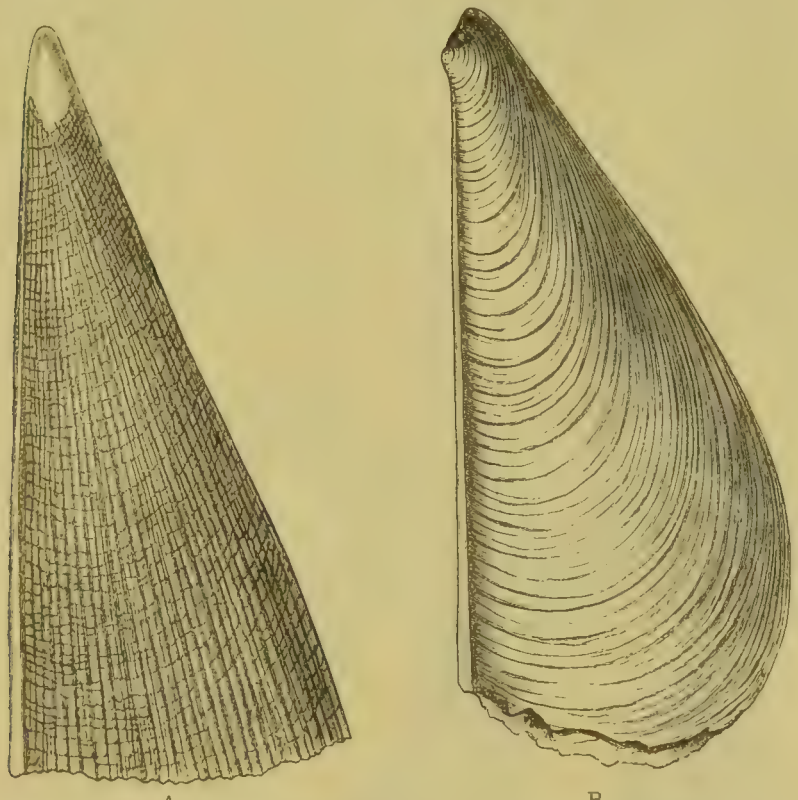


Fig. 579.—A, *Pinna flabelliformis*, the hinder part of the shell being broken away, reduced in size; B, *Aviculopinna membranacea*. From the Carboniferous Limestone of Belgium. (After De Koninck.)

of this group, the shell (fig. 579) is equivalve and wedge-shaped; the beaks are placed quite at the anterior end of the shell, and the posterior end is truncated and gaping. The hinge is toothless, and there is an elongated ligamental groove. The shell consists almost entirely of the external prismatic layer, the inner nacreous layer being of extreme tenuity. The earliest types of *Pinna* appear in the Devonian rocks, and some of these have been separated by Hall to form the genus *Palæopinna*, on the ground of the convexity

of their valves and the fine striation of the surface. In the Carboniferous rocks the genus is represented by large forms, and numerous later types are known, the existing species having a wide range in space.

In the Jurassic and Cretaceous genus *Trichites* the shell is of large size and great thickness, with a marked fibrous structure, the valves being of unequal size, with twisted beaks and undulated margins. The hinge-line is linear and edentulous, and the impression of the posterior adductor is very long and narrow. Lastly, in the Carboniferous and Permian genus *Aviculopinna* (fig. 579, B), the beaks are placed a little way behind the anterior extremity of the shell, and the surface is nearly smooth, and is marked with concentric striæ.

Family 2. Mytilidæ.—In this family the foot is cylindrical, grooved, and byssiferous, and there are two adductor impressions, that of the anterior adductor being small and terminal in position, while that of the posterior adductor is of large size. The shell is mostly equivalve, wedge-shaped or oval, with anteriorly-placed beaks, not alate, and without a byssal notch; the byssus passing between the slightly gaping ventral margins of the valves. The cardinal margin is oblique; the hinge is edentulous; and the ligament is long, linear, and marginal. The pallial line (except in *Dreissenomya*) is entire. The shell is composed of an inner nacreous layer and an outer cellulo-prismatic stratum, with a horny epidermis. The *Mytilidæ* are partly marine and partly inhabitants of brackish or fresh water, and the earliest types of the family appear to be found in the Devonian rocks.

In the genus *Mytilus* are the true "Mussels," in which the shell is very inequilateral and wedge-shaped, and the beaks are terminal in position. Numerous fossil forms are known, commencing in the Trias, and the genus is largely represented at the present day. The Palæozoic shells which have been placed under *Mytilus* probably belong really to other genera. The genus *Modiola*, comprising the "Horse-mussels," is hardly separable, so far as the shell is concerned, from *Mytilus* proper, the principal differences being that the shell is rather oblong than cuneiform, and the beaks are rounded, and are placed a little behind the anterior extremity (fig. 580). The genus *Modiola* appears to be



Fig. 580.—Exterior and interior of the left valve of *Modiola subcarinata*, from the Eocene Tertiary of the Paris Basin.

represented in formations as ancient as the Devonian and Carboniferous, but most of the fossil species are Secondary and Tertiary, and there are also numerous living forms. The Recent and Tertiary genus *Septifer*, again, differs from *Mytilus* in having a calcareous shelf within the beak for the attachment of the anterior adductor muscle. The "Date-shells" (*Lithodomus*) are nearly related to *Modiola*, and are distinguished by their long, cylindrical, anteriorly-inflated shell, and by their habit of forming perforations in rocks, in which they live. They appear to date from the Carboniferous rocks, and are known to palæontologists by both their shells and their burrows. *Crenella*, of the Cretaceous, Tertiary, and Recent deposits, is another ally of *Modiola*.

The genus *Dreissena* (including *Congeria*) comprises Mussel-shaped Bivalves, with terminal beaks (fig. 581), and a small byssal notch in the right valve, but differing from *Mytilus* in having keeled valves, and in the fact that the internal lining of the shell is not nacreous. The hinge is toothed, and the anterior adductor is attached (as in *Septifer*) to a calcareous shelf within the beak. The living species of *Dreissena* are inhabitants of fresh or brackish

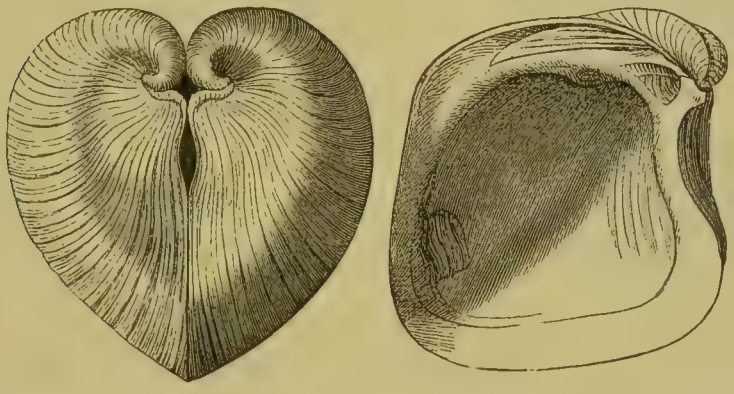


Fig. 581.—*Dreissena* (*Congeria*) *conglobata*, from the Upper Miocene of the Vienna basin. (After Zittel.)

waters, and have a very wide distribution. Fossil forms of the genus are found, often in extraordinary profusion, in the Miocene and Pliocene deposits of Central and Eastern Europe, certain of the Tertiary beds of Austria and Hungary being, for this reason, spoken of as the "Congerien-schichten." The Miocene genus *Dreissenomya* is related in most respects to *Dreissena*, but exhibits the remarkable feature that the pallial line is sinuated.

It is, lastly, probable that the thin-shelled Carboniferous Bivalves which constitute the genus *Anthracoptera* are brackish-water forms, and are allied to *Dreissena*. In general form *Anthracoptera* re-

sembles *Myalina*, but it is destitute of the thick striated hinge-plate of the latter, and the ligament is external.

Order IV. Arcacea.

In this order the mantle-lobes are completely separate, or may form two respiratory siphons; the foot is byssiferous or grooved; and there are two adductors. The shell is ordinarily equivalve, and the hinge is furnished in both valves with a series of equal and similar teeth. This division of Bivalves includes the two families of the *Arcidæ* and *Nuculidæ*, both of which have representatives in rocks as ancient as the Ordovician, at any rate.

Family 1. Arcidæ.—In this family the muscular impressions are nearly equal, the foot is large, bent, and deeply grooved, and the mantle-lobes are separate. The shell is equivalve, and the hinge is long and carries numerous comb-like teeth. The ligament is usually external, attached to a striated area below the beak, but it may be internal, and contained within a single groove. The family of the *Arcidæ* appears to be represented in the Upper Cambrian deposits (*Glyptarca*) and is largely developed in existing seas.

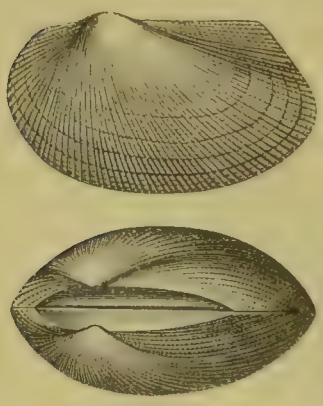


Fig. 582.—*Arca antiqua*. Permian.

In the genus *Arca* (fig. 582) the shell is transversely elongated and inequilateral, the surface being generally ornamented with radial ribs or striæ. The hinge-line is straight, and is furnished with numerous transverse equal teeth. The beaks are remote from one another, and are separated by an oval or lozenge-shaped, striated ligamental area. Taken as a whole, the genus *Arca* ranges from the Upper Cambrian to the present day, the oldest types (*Glyptarca*) appearing in the Lower Tremadoc beds.

The genus *Arca* has been broken up into numerous sub-genera, of which the two most important are *Carbonarca* and *Isoarca*. The former of these comprises some types from the Carboniferous Limestone, in which the beaks are tumid and incurved, and the hinge has two strong oblique teeth in front, and numerous transverse teeth behind. The forms included under the head of *Isoarca* belong to the Jurassic and Cretaceous rocks, and have an elongated, very inequilateral shell, with the beaks near the anterior end. The beaks are inflated and incurved, and the hinge-line is slightly curved, and has a row of transverse teeth on each side.

Closely allied to *Arca* is the genus *Cucullæa*, in which the shell is trapezoidal and ventricose; the hinge-line is straight; and the hinge-

teeth are few and oblique, and at each end of the hinge become parallel with the cardinal margin. The genus *Cucullæa*, in the wide sense, ranges from the Carboniferous period to the present day, but it is a matter of great difficulty to separate the fossil forms of this genus from those belonging to *Arca*.

The genus *Cucullæa* has been divided into sub-genera, of which the two most important are *Macrodon* and *Parallelodon*. In the former of these (fig. 583, E) the shell is greatly elongated, with a long hinge-line, the portion of which in front of the beaks carries a number of short

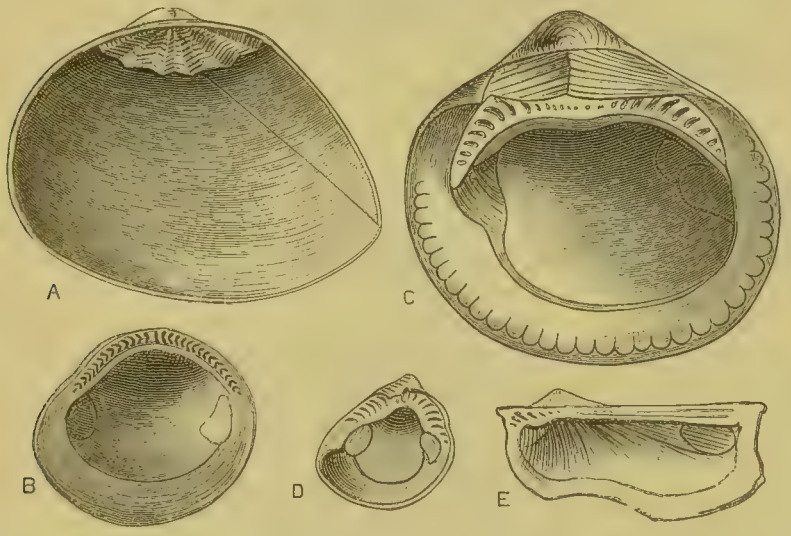


Fig. 583.—Types of *Arcidæ* and *Nuculidæ*. A, Interior of *Lyrodesma Cincinnatiensis*, showing the hinge, enlarged three times—Ordovician (after Hall); B, Interior of *Tellinomya pectunculoides*, showing the hinge and adductor scars, enlarged twice—Ordovician (after Hall); C, Interior of the right valve of *Pectunculus subpilosus*—Tertiary; D, Interior of the valve of *Limopsis aurita*—Pliocene; E, Interior of *Macrodon Hirsonensis*—Jurassic.

oblique teeth, while the portion behind the beaks supports a few elongated teeth which run nearly parallel with the cardinal margin. Forms of this type are not uncommon in the Secondary rocks, but the earliest representatives appear in the Devonian rocks, and a single species exists at the present day. The sub-genus *Parallelodon* is very closely allied to *Macrodon*, possessing the same elongated posterior teeth directed parallel to the hinge-line, but the anterior teeth are also sub-horizontal. The species of this type are principally Carboniferous and Permian.

In the genus *Pectunculus* (fig. 583, C), the shell is nearly round and almost equilateral; the beaks are separated by a striated ligamental area of triangular form; the hinge-line is *curved;* and the hinge-teeth are oblique and form a semicircular row. *Pectunculus* is a comparatively modern genus, and does not seem to have come into existence before the Cretaceous period. Numerous species are known in the Tertiary rocks, and there are about sixty living types of the genus.

Limopsis, ranging from the Trias to the present day, has an orbicular, but slightly oblique shell (fig. 583, D), with a central triangular cartilage-pit, and a row of transverse teeth on each side of this. Lastly, the Miocene and Pliocene genus *Nuculina* has the shell oval or subtrigonal, with the anterior side abbreviated; the hinge-line being curved, and carrying a row of short transverse teeth completed posteriorly by one elongated lamelliform lateral tooth.

In connection with the present family we may consider the extinct genera *Cardiola* and *Cyrtodonta*, with some forms allied to the last of these, the precise affinities of these being uncertain. In the genus *Cardiola* (fig. 584) the shell is thin, equivalve, and oblique, with convex valves and prominent incurved beaks, and having the surface adorned with radiating grooves, which are crossed by concentric furrows in such a way as to give rise to radiating rows of tubercular eminences. There is a large triangular, transversely-grooved ligamental area below the beak, and the hinge-line is straight; but teeth have not been certainly detected in the typical forms of the genus, and the muscular impressions are unknown. Numerous species of the genus have been recognised in the Silurian and Devonian rocks, a characteristic species from the former system being the well-known *Cardiola interrupta*.

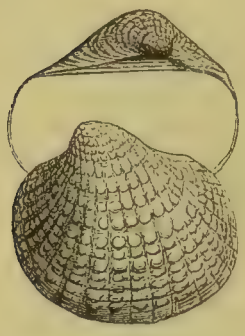


Fig. 584.—*Cardiola cornucopiæ*, from the Devonian rocks of Germany, of the natural size. (After Zittel.)

The shells of the genus *Cyrtodonta* (*Palæarca* of Hall) are ventricose and very inequilateral, the umbones being anterior (fig. 585). The hinge-area is undefined, and the surface is generally smooth. There are a few (three) anterior cardinal teeth, and "two or three remote oblique posterior teeth parallel to the hinge-margin" (Salter). The species of *Cyrtodonta* appear to be exclusively confined to the Ordovician, Silurian, and Devonian rocks, but the genus is said to occur in the Upper Cambrian. *Vanuxemia* comprises forms of the genus with nearly terminal beaks. In the genus *Megalomus*, again (fig. 586), are comprised forms essentially similar to *Cyrtodonta* (possibly identical with it), but having an excessively thickened and massive shell, which is usually strongly inflated. The valves are equal; the beaks strongly incurved and placed anteriorly; the hinge-line furnished with three or four (?) strong transverse teeth; and the anterior muscular impression extremely deep. The forms of this genus appear to be confined to the Silurian rocks, and often attain a great size, but they usually occur in the state of casts only.

Family 2. Nuculidæ.—This family comprises a number of marine Bivalves, in which the mantle-lobes may be open, or siphons may be

present, while the foot is discoid, and there are two nearly equal adductors. The shell is equivalve, with an internal or external ligament, but without a ligamental area; and the hinge is furnished with numerous narrow teeth. The pallial line may be entire or sinuated. This family includes two related groups, typified respectively by *Nucula* and *Nuculana* (*Leda*), the former group being characterised by the fact that the pallial line is entire and the posterior

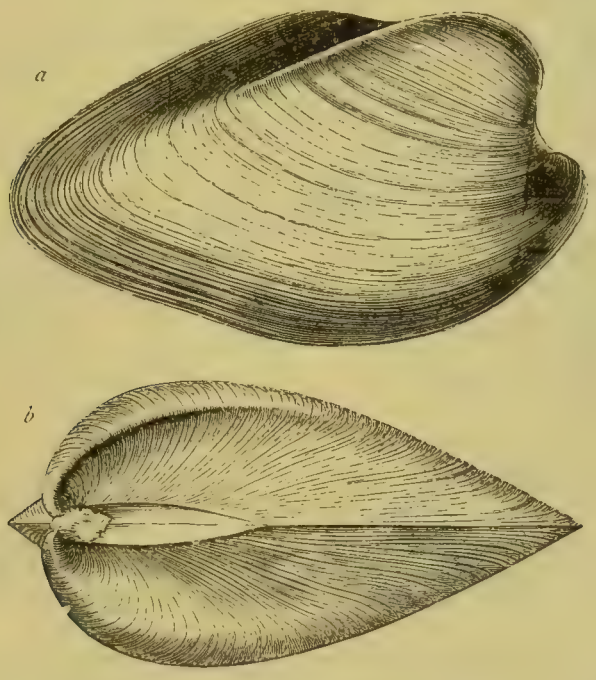


Fig. 585.—*Cyrtodonta Hindi.* (Billings.) Ordovician. *a*, Side view; *b*, Dorsal view.

side of the shell is short, while in the latter the pallial line is more or less sinuated and the posterior side of the shell is long.

In the genus *Nucula* itself (fig. 587) the shell is trigonal or oval, and the beaks are reversed and turned towards the posterior side of the shell, which is also the shortest side. The interior of the shell is nacreous and the ventral margin may be smooth or finely denticulated. The hinge is angulated, and shows a central internal cartilage-pit, flanked on each side by numerous teeth. The Secondary and Tertiary rocks have yielded a considerable number of species of *Nucula*, and there are many living forms. The Palæozoic shells which have been referred to *Nucula* probably belong really to other types (*Tellinomya*, &c.)

In the neighbourhood of the preceding may be placed the Silurian and Devonian genus *Cucullella* (fig. 589, B), in which the hinge-line is straight

or slightly curved, and the hinge is essentially similar to that of *Nucula*, except that the ligament is external; but there exists a long internal septum, which extends from below the beak towards the anterior muscular impression. The genera *Cleidophorus* (Ordovician and Silurian) and *Redonia* (Cambrian and Ordovician) appear to be related to *Cucullella*,

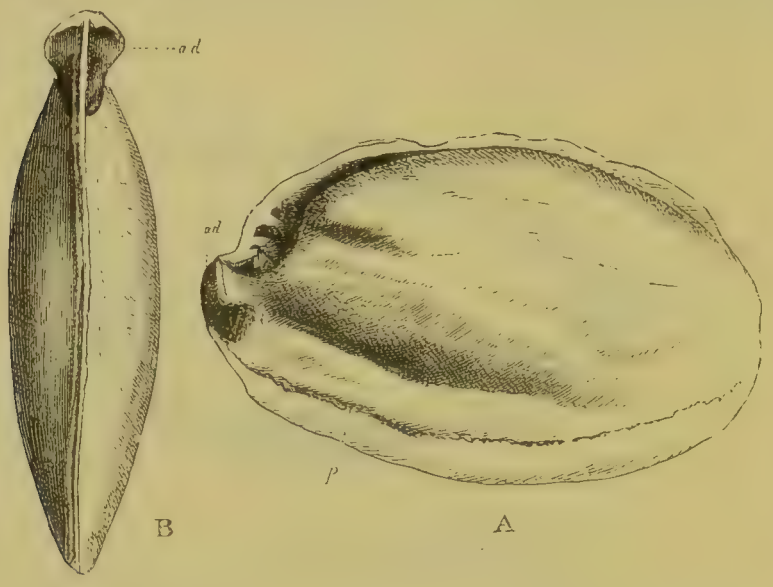


Fig. 586.—*Megalomus compressus.* A, Side view of the cast of the shell, natural size; B, The same viewed from above: *ad*, Cast of the adductor impression; *p*, Pallial line. (Original.)

since both possess a vertical internal plate, which commences in front of the beaks, and is continued downwards behind the anterior adductor, a deep slit being left in the cast of the shell by its removal.

Also in the neighbourhood of *Nucula* may be placed the genus *Tellinomya* (= *Ctenodonta*, Salter), though this type shows decided

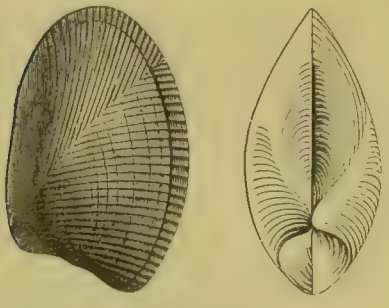


Fig. 587.—*Nucula bivirgata.* Gault.



Fig. 588.—*Tellinomya contracta.* Ordovician. *a*, Interior of right valve; *b*, Exterior of the same.

affinities with *Pectunculus* among the *Arcidæ*. In *Tellinomya* (figs. 583, B, and 588) the posterior side of the shell may or may not be the shortest, and the ligament is external, and is not placed, as in

Nucula, in an internal pit. The shell is generally oval or elongated, smooth, or marked with fine concentric lines; there is no ligamental area (as there is in *Pectunculus*), but the hinge carries numerous small transverse teeth. The species of *Tellinomya* range from the Ordovician to the Carboniferous, and the forms placed by Hall under the genus *Palæoneilo* are probably congeneric with the above.

The genus *Nuculana* (*Leda*) is the type of another group of the present family, which is distinguished by the fact that the shell is more or less produced posteriorly, and also usually by a more or less marked sinuation of the pallial line (589, A); for which reasons these forms are sometimes considered as constituting a separate family (*Nuculanidæ*). In *Nuculana* (*Leda*) the shell (fig. 589, A)

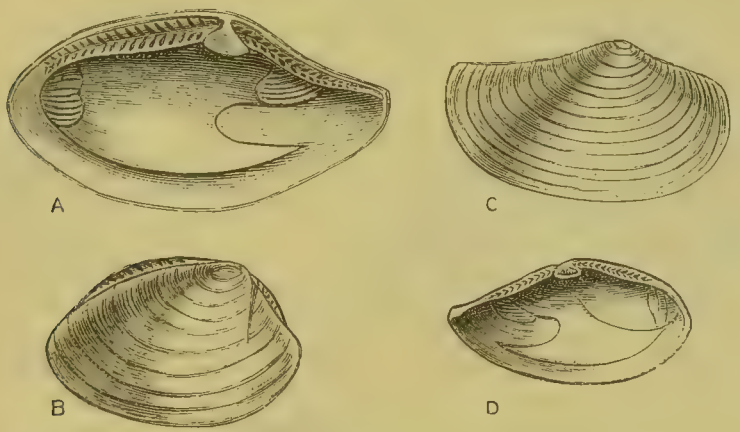


Fig. 589.—Types of *Nuculidæ*. A, Interior of the right valve of *Nuculana* (*Leda*) *lanceolata*—Pliocene; B, *Cucullella ovata*—Silurian; C, *Yoldia striatula*—Cretaceous, enlarged; D, Interior of the left valve of *Yoldia myalis*—Pliocene.

resembles that of *Nucula*, but is rounded in front and produced behind, while the pallial line is generally more or less indented. The hinge has numerous small teeth on either side of a small central cartilage-pit. Various species of the genus have been described from the Palæozoic rocks, beginning in the Devonian, and it is abundantly represented in the Secondary, Tertiary, and Post-Tertiary deposits, as well as by living forms. *Yoldia* (fig. 589, C and D) resembles the preceding in most respects, but the teeth are comb-like, and there is a large pallial sinus. The genus is perhaps represented as early as the Devonian or Carboniferous, but can hardly be distinguished from *Nuculana* in the fossil condition.

In the neighbourhood of *Nuculana* may be placed the Ordovician genus *Lyrodesma*, in which there is an equivalve oblique shell, truncated posteriorly, with an external ligament, and having a hinge of several

transverse teeth radiating in a fan-shaped manner from the beak (fig. 583, A). The Ordovician genus *Actinodonta* only differs from *Lyrodesma* in having a longer hinge-line, and in the fact that the central hinge-teeth are short or obsolete.

Order V. Submytilacea.

This order is defined by Fischer as comprising marine or fresh-water Bivalves, in which the mantle-lobes are free, with thickened margins; the foot may or may not be byssiferous, and there are (except in *Mülleria* only) two adductor muscles. The shell is almost always equivalve, the interior of the valves sometimes nacreous, sometimes not; the hinge is furnished with teeth, which are differentiated into a "cardinal" and two "lateral" series; the ligament is external; and the pallial line is simple. Dr Fischer includes in this order a number of families, of which the most important are the *Modiolopsidæ*, *Trigoniidæ*, *Unionidæ*, *Cardiniidæ*, *Carditidæ*, *Astartidæ*, and *Crassatellidæ*.

Family 1. Modiolopsidæ.—In this family the shell is equivalve and very inequilateral, the beaks being placed subterminally towards the anterior end of the shell. There are two adductor impressions, of which the anterior is smaller than the posterior, and the pallial line is entire. The ligament is external, and the hinge may or may not be furnished with teeth. The principal genus of this family is *Modiolopsis* itself (fig. 590), in which the shell is elongated, re-

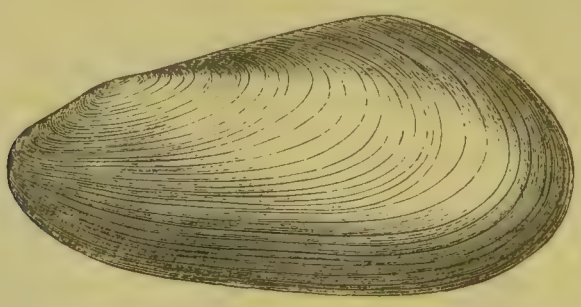


Fig. 590.—*Modiolopsis modiolaris.* Ordovician.

sembling that of a *Modiola* in shape, with anterior beaks, and having the surface smooth, or marked by fine concentric lines of growth. The posterior end of the shell is broader than the anterior; the hinge-line is long and nearly straight, and there is a long ligamental groove extending to the posterior extremity, no teeth being apparently developed. The impression of the anterior adductor is small but deep, that of the posterior adductor being wide and ill-defined. The species of *Modiolopsis* are Ordovician and

Silurian. The Devonian genus *Modiomorpha* is closely related to *Modiolopsis*, but the left valve has a single cuneiform tooth, which fits into a corresponding cavity in the right valve.

Family 2. Trigoniidæ.—The members of this family are marine, with a large bent foot, which does not secrete a byssus, and with free mantle-lobes. The shell (fig. 592) is equivalve, subtrigonal, nacreous internally, with an external ligament placed behind the beaks, and a simple pallial line. The hinge-teeth are few in number (fig. 591), varying from one to three in each valve. The only living genus in this family is *Trigonia* itself, but various extinct types may be associated with this.

In the genus *Trigonia* (figs. 591-593) the shell is thick, nacreous internally, trigonal in shape, and very inequilateral, the beaks being



Fig. 591.—Interior of the left valve of *Trigonia pectinata*. Recent. *ff*, Hinge-line, with teeth and sockets; *a*, Anterior adductor impression; *a'*, Posterior adductor impression.

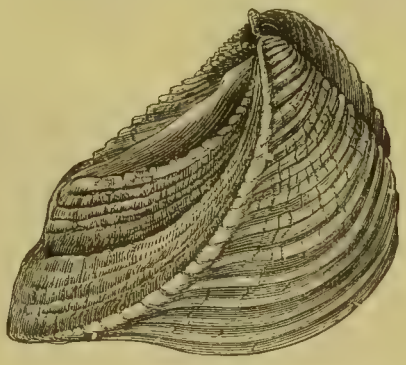


Fig. 592.—*Trigonia costata*, from the Jurassic rocks.

directed backwards. The anterior side of the shell is rounded, and the posterior side is produced and obliquely truncated, constituting a special "area," which is often ornamented differently to the rest of the shell, from which it is divided off by a more or less pronounced ridge running from the beak to the hinder margin. The so-called "escutcheon" is a smaller area, which is cut off from the rest of the shell by a second oblique ridge running close to the dorsal margin of the shell behind the beaks. The hinge of the right valve is furnished with two diverging teeth, the faces of which are strongly striated; while that of the left valve has a strong central tooth, striated on both sides, and two lateral, externally striated teeth. The surface of the shell is rarely almost smooth, the majority of species exhibiting a characteristic ornamen-



Fig. 593.—*Trigonia scabra*. Chalk.

tation, consisting sometimes of concentric lines, but more usually taking the form of radial rows of tubercles or diverging ribs. By the form of the shell and the ornamentation of the surface the species of *Trigonia* may be divided into a number of minor groups. The earliest types of *Trigonia* appear in the Lias, and the genus exhibits an extensive development in the later Jurassic and Cretaceous formations. A few Tertiary species are known, and the Australian seas are inhabited by five existing forms.

The Triassic genus *Myophoria* (fig. 594) comprises sub-triangular shells, obliquely keeled, smooth, concentrically striated, or with a partial development of radiating ribs. The left valve has three, and the right two, cardinal teeth. In the genus *Schizodus* (= the *Axinus* of many authors, but not of Sowerby) are comprised a number of Carboniferous and Permian Bivalves, in which the shell (fig. 595) is obliquely ovate, and is in many respects externally

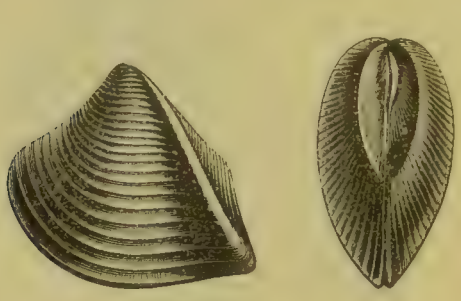


Fig. 594.—*Myophoria lineata.* Trias.



Fig. 595.—Cast of *Schizodus obscurus*, from the Permian rocks, of the natural size. (After Zittel.)

similar to *Myophoria*, except that the surface is smooth and non-plicate, while the posterior side is bounded by an obscure oblique ridge, and is not markedly angular. The right valve has two diverging teeth, and the left valve has a strong central tooth, with a smaller marginal tooth on each side. The Devonian genus *Curtonotus* and the Carboniferous *Dolabra* may be provisionally associated with the present family.

Family 3. Unionidæ.—In this family the foot is large and compressed, not byssiferous except in the fry; the mantle-lobes are more or less free, being usually united between the siphonal apertures; and there are two adductor muscles. The shell is ordinarily equivalve, nacreous internally, with a thick epidermis, and a large external ligament. The hinge may be edentulous or furnished with well-developed teeth, and the pallial line is entire. All the members of this family are inhabitants of fresh water, and they are, therefore, not known in the fossil condition except in fluviatile and lacustrine deposits. If *Anthracosia* and *Carbonicola* be removed to the *Cardiniidæ*, the genera *Unio* and *Anodonta* are the only types of this family which need consideration here.

The shell in the genus *Unio* (fig. 596) is generally oval or elongated, the beaks being placed towards the anterior end, and a prominent external ligament being present. The surface is smooth, concentrically striated, or in some cases ribbed, and is covered with a thick horny epidermis, which is often destroyed over the beaks. The hinge of the right valve has two anterior lateral teeth, and a long laminar posterior lateral tooth; while that of the left valve has a single anterior lateral tooth, a cardinal tooth, and two laminar posterior lateral teeth. The most ancient fossil representatives of the River-mussels appear in the Purbeck beds (Upper Jurassic), and other forms (*Unio Valdensis*, &c.) are found in the Wealden deposits. A considerable number of Tertiary types of *Unio* have been recognised, principally in the Miocene beds, but the genus attains its maximum at the present day.

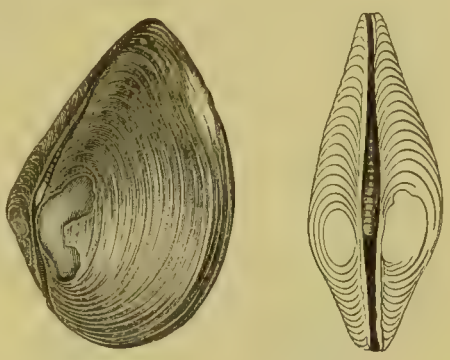


Fig. 596.—*Unio Valdensis*. Wealden (Lower Cretaceous).

The genus *Anodonta* or *Anodon* comprises the living Swan-mussels, and is distinguished from *Unio* by the tenuity of the shell and the edentulous character of the hinge. The shell forms an elongated oval, compressed in the young condition but convex when old, with anteriorly placed beaks; and it often attains a considerable size. The earliest undoubted fossil forms of this genus appear in the Eocene Tertiary; but the Upper Devonian rocks of Ireland and Scotland have yielded the remains of a large Bivalve which has been referred here under the name of *Anodonta* (*Archanodonta*) *Jukesi*.

Family 4. Cardiniidæ.—This family was proposed by Zittel to include a number of Bivalves, in which there is an equivalve, oval, or trigonal shell, which is not nacreous internally, and in which the surface is smooth or concentrically striated. The ligament is external, the pallial line is entire, and the muscular impressions are deep and simple. The cardinal teeth are generally small, but the lateral hinge-teeth are more or less developed, and are often very thick. The forms included in this family are all extinct, and present relationships on the one hand to the *Unionidæ* and on the other hand to the *Astartidæ*. From the fossils with which they are associated, they would appear to have been marine, or to have inhabited brackish waters.

In the genus *Cardinia* (fig. 597, B) the shell is trigonal or ovate,

very inequilateral, posteriorly attenuated, and not ventricose. The ligament is external, in a deep furrow, and the cardinal teeth are feebly developed or wanting, while there is a single prominent lateral tooth on each side. The surface is smooth or concentrically striated, and the beaks are not eroded. The genus is extinct, and is confined to the Triassic and Jurassic rocks. *Trigonodus*, of the Trias (fig. 597, c), is closely allied to *Cardinia*, but the cardinal



Fig. 597.—Types of *Cardiniidæ*. A, *Anthracosia Lottneri*, from the Coal-measures of Germany; B, Interior of the right valve of *Cardinia Listeri*, Jurassic; C, Cast of the interior and hinge-line of *Trigonodus Sandbergi*, from the Trias of Würtemberg; D, Interior of the left valve of *Guerangeria Davousti*, from the Inferior Devonian of France. (After Zittel, Œhlert, and Woodward.)

teeth are more fully developed, the right valve having one and the left valve two. Various Palæozoic shells have been referred to *Cardinia*, but the true affinities of these are doubtful.

We may place in this family the Devonian and Carboniferous genus *Carbonicola*, comprising Unionoid Bivalves, with thick shells, an external ligament, and a concentrically-striated surface. The beaks are not eroded; and the hinge has a thick cardinal tooth in the right valve, with a long lamellar lateral tooth on each side.

The genus *Anthracosia* comprises a number of thin-shelled Bivalves in which the shell is long-oval and inequilateral (fig. 597, A), and the surface is smooth or concentrically-striated. The ligament is external, and the hinge seems to have been provided with a single cardinal tooth in each valve, without lateral teeth. The *Anthracosiæ* are found in abundance in parts of the Coal-measures and Lower Permian series, and they may perhaps have been inhabitants of brackish water.

Lastly, we may place here the Lower Devonian genus *Gueran-*

geria, of Œhlert, in which the shell (fig. 597, D) is long-oval and very inequilateral, with small subterminal beaks, and a concentrically-striated surface. The ligament is external; both valves have an elongated posterior lateral tooth; and the right valve has a cardinal tooth which fits into a corresponding socket in the left valve.

Family 5. Carditidæ.—In this family the mantle-lobes are free, the foot is byssiferous or is grooved inferiorly, and there are two adductor muscles. The shell is equivalve, solid, cordate, oval, or transversely elongated, and generally adorned with radiating ribs. The pallial line is entire; the ligament is almost always external; and the hinge is massive, and supports one or two oblique cardinal teeth and sometimes lateral teeth as well. The members of this family are marine in habit, and the two most important recent genera are *Venericardia* and *Cardita*, which are closely related to one another, and are separated principally by characters connected with the living animal, the former having a large foot which is grooved and non-byssiferous, while in the latter the foot is short and secretes a byssus.

In both *Venericardia* and *Cardita* the shell (fig. 598) is massive, more or less cockle-shaped, inequilateral, and adorned with radiat-



Fig. 598.—*Venericardia* (*Cardita*) *planicosta*. Eocene Tertiary.

ing ribs, the ventral margin being denticulated or crenulated. The ligament is external, and the hinge-plate is thick and furnished with powerful cardinal and variably developed lateral teeth. The genus *Cardita* ranges in time from the Trias to the present day; while the species of *Venericardia* abound in the Cretaceous and Tertiary rocks, and a few forms still survive.

With the preceding may be associated, provisionally at any rate, a number of wholly extinct genera. Of these the genus *Pleurophorus* (fig. 599) possesses an oblong shell, with anterior, almost terminal beaks, and a massive hinge. Each valve has two diverging cardinal teeth, with a single elongated lateral tooth placed posteriorly; and the anterior adductor impression is very deep,

and is bounded behind by an elevated ridge. The species of *Pleurophorus* range from the Devonian to the Trias, but they are most characteristic of the Permian formation. Possibly allied to the above is the *Matheria* of the Ordovician rocks of Canada, in which the beaks are placed anteriorly and the ligament is external; and the Silurian genus *Anodontopsis* may, perhaps, also find a place here.

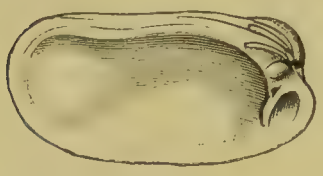


Fig. 599. — Interior of the left valve of *Pleurophorus costatus*, from the Permian rocks. (After King.)

In this neighbourhood Dr Fischer likewise places the extinct genera *Myoconcha* and *Hippopodium*. In the former of these the shell is thick and mussel-shaped, with nearly terminal beaks, and having the ligament external and contained in a groove. The hinge is massive and curved, and in the right valve carries a single oblique tooth. The anterior adductor impression is deep, and the pallial line is entire. The species of *Myoconcha* are essentially characteristic of the Secondary rocks, though the genus has been stated to occur in the later Palæozoic deposits. In the genus *Hippopodium* (fig. 600) the shell is oblong, massive, and ventricose, with nearly terminal incurved beaks, an external

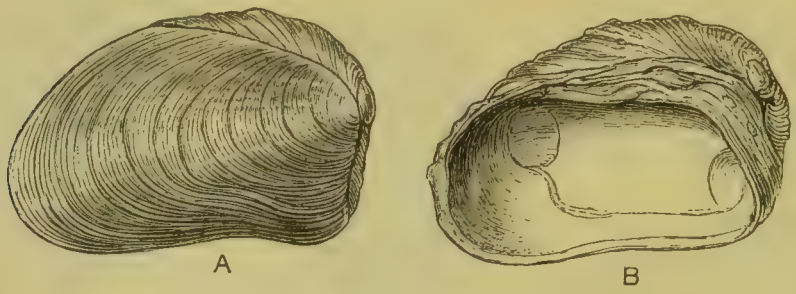


Fig. 600.—*Hippopodium ponderosum*. Lias.

ligament, and an entire pallial line. The hinge carries in each valve an oblique tooth, which becomes obsolete with age. The genus is confined to the Jurassic rocks, a familiar species being the *Hippopodium ponderosum* of the Lias.

Family 6. Astartidæ.—In this family the mantle-lobes are free, and the foot is long and pointed. The shell is equivalve, thick, trigonal or oval, with a more or less distinct "lunule." The ligament is external, and the hinge thick, with two or three cardinal teeth in each valve, the lateral teeth being obsolete. There are two adductor impressions, of which the anterior is the deepest, and the interior of the shell is not pearly. The members of this family are all marine, and the principal genera are *Astarte* and *Opis*.

In the genus *Astarte* (fig. 601) the shell is thick, and usually concentrically furrowed, subtrigonal, rounded, or oval in form, inequilateral, and usually with a well-marked "lunule." The ligament is external, and there are two cardinal hinge-teeth in each valve, the front tooth of the right valve being large and thick. The genus *Astarte* is stated to occur in the Palæozoic series, from the Silurian onwards; but the affinities of the supposed ancient representatives of this type are uncertain. From the Mesozoic deposits numerous species of *Astarte* have been obtained, and the genus attained its maximum development at this period. The Tertiary species are fewer in number, and about a score of living species are known. The Carboniferous genus *Astartella* and the *Cypricardella* (*Microdon*) of the Devonian and Carboniferous rocks appear to be related to *Astarte*. The genus *Pachydomus*, of the Devonian rocks of Australia and Tasmania, may, perhaps, also be placed in this family.

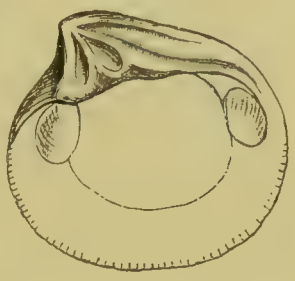


Fig. 601. — Interior of the right valve of *Astarte detrita*. Jurassic.

Of the remaining genera of the *Astartidæ*, the only one which need be specially noticed is *Opis*, of which numerous species are found in the Triassic, Jurassic, and Cretaceous rocks. In this genus the shell (fig. 602) is heart-shaped and keeled, with prominent incurved beaks, a distinct lunule, and a single cardinal tooth in each valve.



Fig. 602.—Interior of the right valve of *Opis lunulata*. Jurassic.

Family 7. Crassatellidæ. — The general characters of the animal in this family are similar to those in the *Astartidæ*.

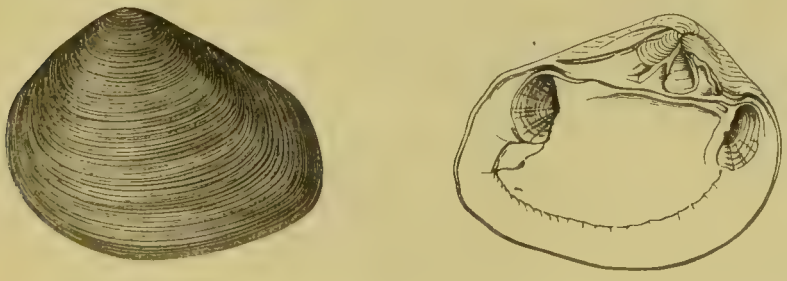


Fig. 603.—*Crassatella ponderosa*. Eocene Tertiary.

The shell also agrees with that of the *Astartidæ* in being equivalve, massive, and subtrigonal, with a distinct "lunule." The shell is, however, more or less produced posteriorly, and the ligament is lodged in an internal groove. The type of this family is *Crassatella* itself (fig. 603), in which the shell is thick, solid, and

ventricose, attenuated posteriorly, and having a concentrically furrowed surface. There is a distinct "lunule," and the hinge is broad, with strong cardinal teeth and feebly developed lateral teeth, while there is a well-marked pit in the hinge-plate of each valve for the reception of the internal ligament. The genus is marine; the earliest forms appearing in the Cretaceous rocks, while numerous Tertiary and about thirty-five Recent species are known. The Cretaceous genus *Crassatellina* has been associated with *Crassatella*, but it agrees with the *Astartidæ* in having an external ligament.

Order VI. Erycinacea.

This order is defined by Fischer as comprising marine Bivalves, with a byssiferous foot, and without respiratory siphons, but with the exceptional character that the branchial aperture is placed anteriorly, in front of the pedal opening, instead of being placed posteriorly below the exhalant or anal aperture. The shell is small and thin, equivalve, free, the hinge being toothed or toothless, and an internal cartilage-pit and generally an external ligament being present. There are two adductors, and the pallial line is entire. This order includes the two small families of the *Erycinidæ* and *Galeommidæ*.

Family 1. Erycinidæ.—The shell in this family is small and thin, oval or trigonal in form, equivalve, mostly inequilateral, and smooth or finely striated. The hinge carries one or two cardinal teeth, but lateral teeth are not constant. The internal ligament is contained in an oblique groove between the hinge-plates of the valves, and the external ligament is feebly developed.

The genus *Erycina* includes a large number of small shells which are found in Tertiary deposits, and are specially abundant in the Eocene rocks. A single species has been described from the Cretaceous rocks of North America. Very closely related to *Erycina*, if generically separable from it, is the genus *Kellia*, which is not known in the fossil condition (as distinct from the preceding). Related genera are *Lepton* and *Montacuta*, both of which are known by Tertiary forms, and still survive.

Family 2. Galeommidæ.—In this family the shell is small, thin, equivalve, and subequilateral, and is more or less gaping. The hinge may be edentulous, or may be provided with one or two teeth; and the ligament is internal, and is lodged in a median pit. All the forms included in this family are marine, the two principal genera being *Galeomma* and *Scintilla*, both of which are represented by living forms. The oldest species of *Galeomma* are found in the Pliocene deposits, while *Scintilla* appears as early as the Eocene.

Order VII. Cardiacea.

The Lamellibranchs included in this order are inhabitants of the sea or of brackish water, and possess a byssiferous or grooved foot; while there are two adductor muscles. (According to the views of

some malacologists, *Tridacna* is monomyary.) The shell is equivalve and thick, the hinge with or without teeth, the ligament external, and the pallial line simple or slightly indented. This division includes the two principal families of the *Tridacnidæ* and *Cardiidæ*.

Family 1. Tridacnidæ.—In this family the shell is equivalve, thick, not nacreous internally, and usually truncated or gaping in front, the ventral margin being undulated or dentate, and the surface ribbed. The hinge has a single cardinal tooth and one or two posterior lateral teeth in each valve, and the ligament is external. The foot is finger-like and usually secretes a byssus; the mantle-lobes are extensively united; and the impressions of the adductors are blended together and are subcentral in position. (According to some authorities, the anterior adductor is really absent.)

In the genus *Tridacna* itself (fig. 604) the shell is massive, of large size, and subtrigonal in form; and there is a wide byssal aperture just in front of the beaks. On the other hand, in the closely

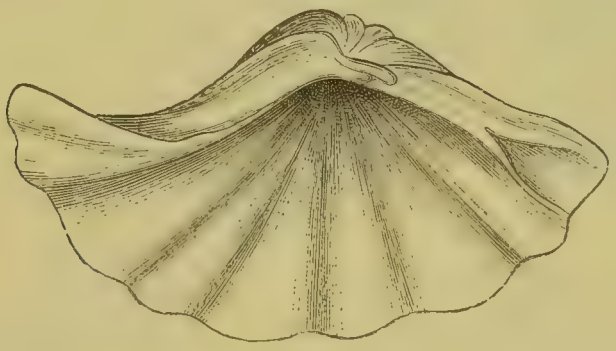


Fig. 604.—*Tridacna media.* Tertiary. Interior of right valve.

allied *Hippopus* the shell is closed, and the pedal aperture is only indicated by small serrations of the margin of the valves. *Tridacna* is only known in a fossil condition by a few species from the later Tertiaries. The Palæozoic *Eurydesma* has also been referred to this family.

Family 2. Cardiidæ.—In this family are included the "Cockles," in which the mantle is open in front to allow of the passage of a large and sickle-shaped foot, while it is closed behind and gives origin to two longer or shorter siphons. The shell is equivalve and is not nacreous, usually heart-shaped in form, with radiating ribs, and with the ventral margin toothed or wavy. The ligament is external, and the hinge carries one or two cardinal teeth in each valve, usually with lateral teeth as well. There are two adductor-muscles, and the pallial line is entire or slightly indented.

In the genus *Cardium* are comprised the true Cockles, in which the shell is ventricose, the beaks pronounced, and placed nearly in

the centre of the dorsal margin, the margins crenated, and the pallial line more or less indented. The surface is adorned with radial ribs or striæ, which often carry spines. A very large number of recent species of *Cardium* are known, and between three and four hundred fossil forms have been referred here. Certain Palæozoic types have been placed under this head, but the affinities of these are doubtful. On the other hand, the genus is largely represented by undoubted types throughout the Mesozoic and Kainozoic series. The genus *Cardium* has been broken up into numerous minor groups, most of which can be with difficulty, or not at all, recognised in the fossil condition. *Papyridea*, *Lævicardium*, and *Lithocardium* are Secondary to Recent types closely allied to *Cardium* proper. *Protocardia* (fig. 605) has the posterior slope of the shell radiately ribbed, while the rest of the shell is concentrically striated. *Hemicardium* has keeled valves, the shell appearing cordate as viewed from behind or in front. *Lymnocardium* and *Adacna* include brackish-water and fresh-water Cockles, in which the cardinal teeth are small or obsolete; and the species of the former are common in some of the fluviatile and estuarine deposits of the Upper Tertiary period. The recent species of *Adacna* are found abundantly in the Black Sea and Caspian Sea, and in the Sea of Aral, often in quite brackish water, and the fossil species are extraordinarily plentiful in the Tertiary deposits of Austria, Hungary, and Southern Russia. The genus is remarkable for the exceeding variability of the hinge as regards the number of teeth. *Byssocardium*, again, includes Eocene and Miocene Cockles, in which the shell is truncated anteriorly, and possesses a large byssal sinus.



Fig. 605.—*Cardium* (*Protocardia*) *Hillanum*. Upper Greensand.

The most remarkable of the early types of the *Cardiidæ* is the genus *Conocardium* (= *Pleurorhynchus*), which ranges from the Ordovician to the Carboniferous, but is specially characteristic of the Devonian and Carboniferous formations. The shell in this genus (fig. 606) is keeled, and very oblique, the *anterior* end (sometimes regarded as the posterior end) of the shell being short and abruptly truncated, so as to appear as a cordate flattened area when the shell is viewed from the front. Just below the beaks the shell is produced anteriorly into a long cylindrical tubular projection or beak. *Posteriorly* the shell is elongated and contracted, the valves being widely deficient or gaping at the extremity. The hinge-line

is long and straight; and two cardinal teeth, with a hinder lateral one, appear to be present.

Family 3. Lunulicardiidæ.—This family is one of very uncertain value, and embraces only the imperfectly understood genus *Lunulicardium* of Münster. In this genus the shell is obliquely oval, equivalve, and inequilateral, the surface being adorned with radiating ribs. The anterior end of the shell is truncated, and the pos-

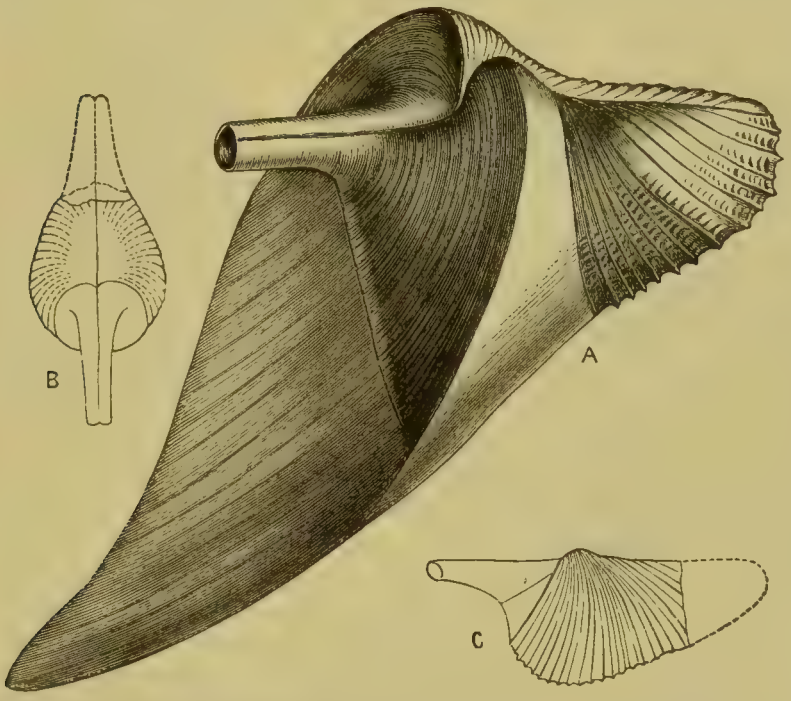


Fig. 606.—A, *Conocardium giganteum*, showing the truncate anterior and produced posterior end of the shell, with the tubular prolongation of the former; B, *Conocardium inflatum*, viewed from above: C. The same viewed laterally. Carboniferous. (After M'Coy.)

terior end is sub-alate. The cardinal line is "marked by a lunate hiatus in each valve, which was probably occupied by the ligament" (Hall). The hinge and muscular markings are unknown. In this genus, as in *Conocardium*, the truncated end of the shell is sometimes regarded as the *posterior* end. The species of *Lunulicardium* are found in the Silurian and Devonian rocks, being very abundant in the Silurian rocks of Bohemia.

Order VIII. Chamacea.

In this order, represented at the present day by the single genus *Chama*, the mantle is closed, the mantle-cavity communicating with the exterior by apertures for the foot and for the in-going and out-

going currents of water; and the foot is rudimentary. The shell is irregular, very inequivalve, always attached to foreign objects by the substance of one valve. In structure, the shell is thick, and consists of an internal porcellanous and an external prismatic layer, often with special and remarkable modifications in particular types. The hinge is thick, and is provided with cardinal teeth, but lateral teeth are wanting. The ligament may be external or internal, or is wanting altogether. The pallial line is entire, and the two adductors leave well-marked scars, or may be inserted upon special internal calcareous septa. This order includes the two families of the *Chamidæ* and the *Rudistæ*.

Family 1. Chamidæ.—In this family the shell is inequivalve, and is generally attached to foreign objects by the substance of one of the valves. The ligament is normally external, and lies in a deep groove, but it may become more or less completely concealed from view. The hinge is massive, and usually carries two teeth in one valve and one in the other. The adductor impressions are very large, and the pallial line is entire. The family includes the single recent genus *Chama*, together with a number of exceedingly remarkable Mesozoic Bivalves, such as *Diceras*, *Requienia*, *Monopleura*, *Caprina*, *Caprotina*, &c. The structure of these latter is, however, so complicated that they cannot be advantageously treated of here except in an exceedingly brief manner; since a full understanding of their characters can only be obtained by the examination of actual specimens.

In the genus *Chama* (fig. 607) the shell is attached to foreign objects by the beak of the left valve, or, more rarely, by that of the right valve. The beaks of both valves are incurved and are directed anteriorly. The free valve is the smallest, and the surface of both valves is furnished with foliaceous expansions, derived from a thick external prismatic layer, below which is situated an internal porcellanous layer. The massive hinge usually carries a single tooth in the free valve, articulating with two teeth in the attached valve. The recent species of *Chama* are all inhabitants of the sea. The fossil species commence in the Cretaceous rocks, a number of forms being found in the Tertiary deposits.



Fig. 607. — Interior of the attached valve of *Chama lamellosa*. Eocene Tertiary.

In the genus *Requienia* (fig. 608) the shell is exceedingly inequivalve, the right valve being small, subspiral, and operculiform, while the left valve is of large size and is spirally rolled up, its beak serving for the attachment of the shell to some foreign body. The ligament is external,

and is prolonged on the outside of the left valve to its beak; and the hinge is edentulous or has a single tooth. The genus is distinguished from *Chama* by its generally smooth or striated surface, and the want of the foliaceous expansions of the latter. The species of *Requienia* are exclusively confined to the Cretaceous period.

In the genus *Diceras* (fig. 609) the shell is slightly inequivalve, the beaks being very prominent and spirally rolled up in both valves.



Fig. 608. — *Requienia ammonia*, one-fourth of the natural size. *a*, Point of attachment. Cretaceous rocks. (After Woodward.)

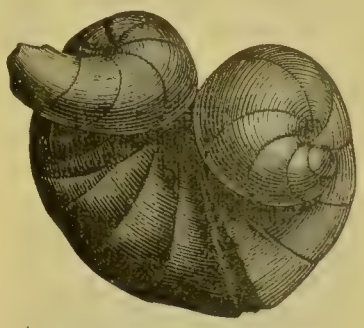


Fig. 609.—*Diceras arietina*. Upper Jurassic.

Either the right or the left valve may be the largest, and in that case serves for the attachment of the shell to foreign bodies by means of the umbo. The ligament is external, and is prolonged to the apices of the beaks in external furrows. The hinge is very thick, with prominent teeth (two in one valve and one in the other); and the muscular impressions are bounded by long spiral ridges. The species of *Diceras* are exclusively confined to the Middle and Upper Jurassic rocks, abounding especially, in some regions, in beds of the age of the Coral-rag of Britain.

In the genus *Monopleura* (fig. 610) the shell is very inequivalve, and is fixed by the apex of the right valve, which is the larger of the two, and is conical in form, being either straight, or more or less spirally inrolled. The left valve is small, and either flat or widely conical, with a submarginal umbo. The ligament is prolonged externally in grooves, which run to the beaks in each valve. The surface is generally radially striated. The species of this genus are wholly confined to the Cretaceous rocks, and principally characterise the lower division of this formation. Closely allied to *Monopleura*, and also confined to the Cretaceous rocks, is the genus *Caprotina*.

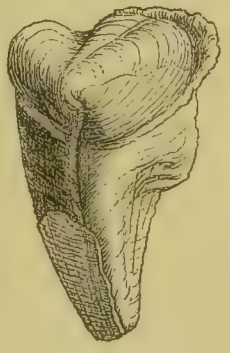


Fig. 610.—*Monopleura trilobata*, of the natural size, viewed from behind. Cretaceous rocks.

Here also must be placed the remarkable Cretaceous genera *Caprina*, *Plagioptychus* (= *Caprina* in part), and *Ichthyosarcolites* (= *Caprinella* and *Caprinula*), in all of which the shell (fig. 611) is very inequivalve, thick-walled, and either fixed by the apex of the right valve, or, in some cases, free. In all these forms the shell-structure consists of a thin external prismatic layer, and a greatly developed internal laminated or porcellanous layer, the laminæ of which may be more or less extensively separated by vacant spaces (the so-called "water-chambers"). In the substance of the left valve in these genera there is, further, developed a



Fig. 611.—*Plagioptychus* (*Caprina*) *Aguilloni*. The right-hand figure shows the interior of the left valve.

system of radial canals which run from the beak to the free margin of the valve, where they terminate in foramina, and which are sometimes simple and sometimes complex in their arrangement.

Family 2. Rudistæ (*Hippuritidæ*).—In this family the shell is very inequivalve (fig. 612), unsymmetrical, massive, the two valves being dissimilar in structure and sculpturing. The shell is attached by the apex of the elongated right valve, which is conical in form; while the left valve is depressed, often operculiform, and has a central umbo. There is no ligament; but the free upper valve is fixed into the conical lower valve by powerful teeth and processes, and is only capable of movement in a vertical direction. There are two large adductor impressions, those of the left valve being upon prominent apophyses. The pallial line is simple and submarginal.

The shell-structure in the *Hippuritidæ* is exceedingly peculiar, and has been described by Zittel as follows: "The *lower* valve consists of two layers, the outer of which is formed of perpendicular prisms having a direction parallel to the long axis of the shell, and intersected by numer-

ous transverse lamellæ, which are horizontal, or are directed somewhat obliquely outwards and upwards, the intersection of the two series giving rise to a lattice-like structure (fig. 614). The shell splits easily along the line of these transverse lamellæ, the upper surfaces of which—as also of the thickened upper margin of the shell—exhibit radially disposed vascular impressions. The inner stratum of the shell is white, porcellanous and laminated in structure. Sometimes the parallel lamellæ are separated by vacant spaces (fig. 613), thus giving rise to intervening lacunæ ('water-chambers'). This is especially the case in *Hippurites*, in which the greater portion of the conical lower valve is formed by the inner shell-layer. The two shell-layers separate readily from one another; and



Fig. 612.—*Hippurites Toucasianus*. A large individual, with two smaller ones attached to it. Cretaceous.

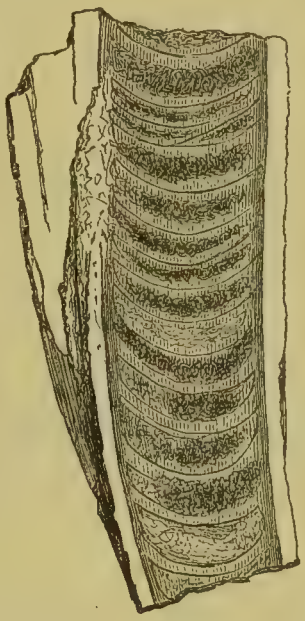


Fig. 613.—Vertical section of a broken shell of *Hippurites organisans*, without the body-chamber, showing the horizontal partitions and intervening spaces ("water-chambers"), of the natural size. (After Zittel.)

as the inner one, at least in *Sphærulites* and *Radiolites*, resists destruction during fossilisation less completely than the outer one, it commonly happens that only the outer layer is preserved, and the mould of the body-chamber appears to be separated from the latter by a vacant space. Still more commonly, the inner layer has undergone transformation, and has been replaced by crystalline calcite. The *upper* valve consists, like the lower one, of two layers, but the cellulo-prismatic outer stratum is mostly of small thickness, and in *Hippurites* is traversed by a complicated system of canals, while the inner porcellanous and laminated layer is frequently converted into crystalline calcite." It is usually supposed that the outer layer of the shell in the *Hippuritidæ* corresponds with the external prismatic layer in such Bivalves as *Pinna*; but it differs from the latter in the great size of the component prisms, and in the fact that

these are directed *parallel* to the surface of the shell instead of perpendicular to the surface. Moreover, the intersection of the prisms by horizontal or oblique lamellæ gives rise to an altogether unique vesicular structure. Further, the prisms in the outer shell-layer in the ordinary Bivalves are solid, whereas in the *Hippuritidæ* they are hollow, and were probably occupied in life by some organic infilling.

The shell of *Hippurites* (fig. 612) is inversely conical or cylindrical, and sometimes attains a length of two or three feet. The shell is attached by the larger conical valve, and is closed by a small depressed free valve, with a central umbo. In *Radiolites* the shell is inversely conical, bi-conical, or cylindrical, with dissimilar valves. The upper valve is sometimes flat, sometimes conical, and has a

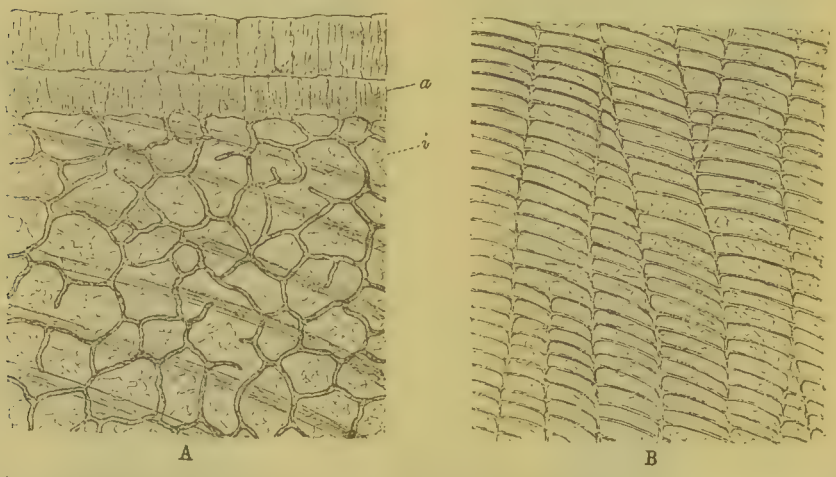


Fig. 614.—Minute structure of the shell of *Sphærulites* (*Radiolites*) *Mortoni*, from the Upper Greensand, Cambridge. A, Transverse section, enlarged ten times, showing the large hollow prisms of the outer layer (*i*) transversely divided, the thin inner layer (*a*) being converted into crystalline calcite; B, Vertical section, similarly enlarged, showing the prisms of the outer layer with their intersecting cross-partitions. (Original.)

central or lateral umbo. The external shell-layer in the lower valve is exceedingly thick, and is made up of hollow calcareous prisms, which run parallel with the surface and are intersected by close-set oblique transverse plates (fig. 614); while the inner shell-layer is comparatively thin. In the typical forms of *Radiolites* the lower valve commonly exhibits on one side two bands running from the beak to the upper margin, which are smooth or striated differently from the rest of the valve. In the closely allied genus *Sphærulites* these bands are wanting.

The *Rudistæ* are not only entirely extinct, but are exclusively restricted to rocks of Cretaceous age, being especially characteristic of the middle and upper divisions of this formation, particular types commonly being confined to special stratigraphical horizons. The Cretaceous deposits of Britain, Europe, Algeria, Asia Minor, Persia,

and North America have yielded the remains of these singular Molluscs; but they are especially abundant in Southern Europe, where they often give rise to great beds of marble ("Hippurite Limestones," "Rudisten-Kalk"). In all the *Rudistæ* the two valves of the shell are more or less conspicuously dissimilar in shape and size, and often in external sculpturing or internal structure. They appear to have lived in shallow water, and to have grown in great beds or banks, much as Oysters do.

Order IX. Conchacea.

In this order, the inhalant and exhalant openings of the mantle are usually prolonged into siphons; the foot may or may not be byssiferous; and there are two adductor muscles. The shell is equivalve, regular, and free; the ligament is almost always external; the hinge has cardinal teeth, generally with lateral teeth as well; and the pallial line is usually sinuated, but may be entire. The Bivalves included in this order are mostly marine, but sometimes inhabit brackish or fresh waters. The principal families included under this head by Fischer are the *Megalodontidæ*, *Cyprinidæ*, *Veneridæ*, *Cyrenidæ*, *Ungulinidæ*, *Unicardiidæ*, *Tancrediidæ*, *Donacidæ*, *Psammobiidæ*, and *Solenidæ*.

Family 1. Megalodontidæ.—In this family the shell (fig. 615) is equivalve, very thick, and mostly smooth or concentrically striated,

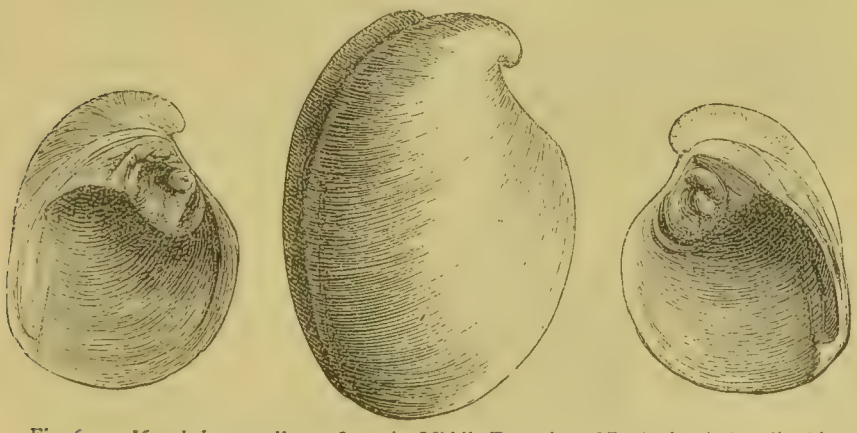


Fig. 615.—*Megalodon cucullatus*, from the Middle Devonian of Paffrath. (After Zittel.)

the beaks being turned to the anterior side of the shell. The hinge-plate is very broad, each valve carrying one or two strong cardinal teeth, with feebly developed lateral teeth. The ligament is external, and the posterior adductor impression is placed upon a more or less prominent ridge. All the genera of this family are extinct, the principal type being *Megalodon* itself. In this genus (fig. 615) the shell

is massive, with subspiral beaks and an external ligament. The right valve has two striated cardinal teeth, and the left valve has one, partially-divided cardinal tooth. The species of *Megalodon* range from the Devonian to the Trias, a familiar species being the *M. cucullatus* of the Middle Devonian rocks. Allied to the preceding is the Jurassic genus *Pachyrisma*, in which the shell is thick and ponderous, and the umbones are subspiral.

Family 2. Cyprinidæ.—In this family the mantle-lobes are united behind by a curtain pierced by two siphonal orifices, and the foot is thick and tongue-shaped. The shell is equivalve, thick, the beaks directed anteriorly and often inrolled, and the hinge is furnished with cardinal and lateral teeth. The ligament is external, and the pallial line is entire.

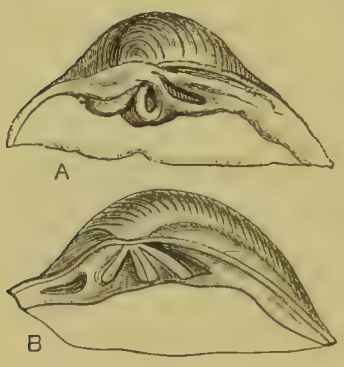


Fig. 616.—A, Hinge of *Cyprina tumida*, Pliocene; B, Hinge of *Cyprina Saussuri*, Cretaceous.

The principal genus in this family is *Cyprina* itself, in which the shell is large, strong, and rounded, with a thick epidermis, and a strong external ligament. The hinge carries two cardinal teeth in each valve, with a single lateral tooth posteriorly, and variably developed anterior lateral teeth (fig. 616). The genus *Cyprina* is represented in recent seas by the familiar *C. Islandica*, and there are numerous Secondary and Tertiary species, commencing in the Lias.

The genus *Isocardia* (fig. 617) comprises the "Heart-cockles," in which the shell is cordiform and inflated, and the beaks are remote and subspiral. The ligament splits in front, and is continued in two separate furrows as far as the beaks. The hinge in each valve possesses two cardinal teeth and a posterior lateral tooth. The genus *Isocardia* is represented by living forms, and the fossil species date from the Jurassic rocks. Most of the Jurassic "Heart-cockles," however, belong to the related genus *Anisocardia*, in which the beaks are approximated and the ligament is not split.



Fig. 617.—*Isocardia crassa*. Pliocene.

Cypricardia (= *Trapezium*) has a trapezoidal shell, usually radiately striated, the hinge with three radiating cardinal teeth and a posterior lateral tooth in each valve, and the posterior side often keeled. The true *Cypricardiæ* are probably wholly Mesozoic and Kainozoic, and a few recent species of the genus are known. It is possible, however, that the Palæozoic genera *Cypricardinia* (Silurian to Carboniferous) and

Goniophora (Silurian and Devonian) should find a place in the neighbourhood of *Cypricardia*.

Family 3. Veneridæ.—In this family the animal is free and locomotive; the mantle has a large anterior opening for the foot; and respiratory siphons, which may be separate or more or less united, are developed. The foot is tongue-shaped and compressed, in some cases grooved and byssiferous. The shell (fig. 618) is regular, suborbicular or oblong, equivalve, and furnished with an external ligament. The hinge usually carries three diverging cardinal teeth, and the development of the lateral teeth is variable. The pallial line usually shows a deeper or shallower sinus, but in some cases is entire. The *Veneridæ* are all marine, and the family includes some of the most highly organised and most beautifully

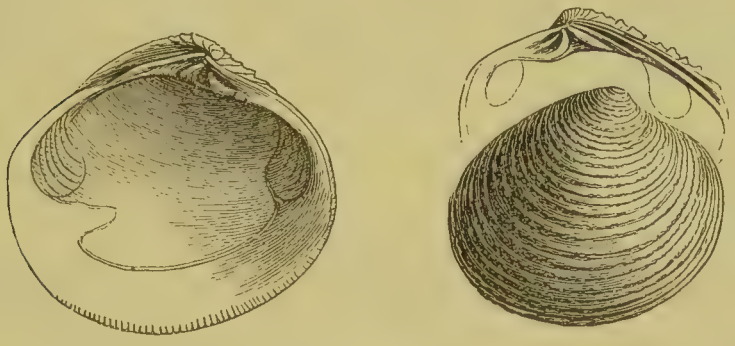


Fig. 618.—*Venus cincta*, from the Miocene rocks of Austria. (After Zittel.)

coloured examples of the entire class of the *Lamellibranchiata*. No Palæozoic representatives of the family have been as yet detected.

In the genus *Venus* (fig. 618) the shell varies greatly in form and in surface-ornamentation, and is principally distinguished by its wide hinge-plate, furnished in each valve with three diverging cardinal teeth. The genus, in its typical form, appears to begin in the Jurassic rocks, and the Tertiary rocks have yielded a large number of forms, while about two hundred species are known to exist at the present day. Very nearly related to *Venus* is the genus *Cytherea* (*Meretrix*), which is largely represented at the present day, and has numerous fossil forms, commencing in the Jurassic rocks.

In the genus *Dosinia* (*Artemis*) the shell is orbicular, compressed, and concentrically-striated, with a deep "lunule" and a deep and pointed pallial sinus (fig. 556, b). The earliest fossil forms appear in the Cretaceous rocks. *Venerupis*, again, has the shell radiately ribbed, and at the same time furnished with concentric ridges, the general form of the shell being oblong. In *Tapes*, lastly, the shell is oblong, with anteriorly placed beaks, a concentrically-striated

surface, and a broad pallial sinus. The genus is known by Cretaceous, Tertiary, and Recent species.

In the singular genus *Thetis*, now usually included here, the shell is gibbous and very thin, and there is an exceedingly deep, angular, pallial sinus, which extends nearly to the beaks. The known species of this genus are found in the Cretaceous rocks. Finally, the genus *Petricola*, now usually regarded as the type of a separate family, comprises Bivalves which differ from the *Veneridæ* in their habit of burrowing into rocks or sand, or in being fixed into crevices by a byssus. The shell in this genus is thin and tumid, with a short anterior side and a deep pallial sinus. The range of the genus is from the Cretaceous period to the present day.

Family 4. Cyrenidæ.—In this family the mantle is open in front; a single siphon is present, or, more usually, two more or less united; and the foot is large and tongue-shaped. The shell is suborbicular, closed, with a thick epidermis and a concentrically-striated surface, the hinge with cardinal and lateral teeth, and the ligament external. The pallial line is simple or slightly sinuated. The members of this family inhabit fresh or brackish waters, and their remains are commonly found in estuarine or lacustrine deposits of Mesozoic and Tertiary age.

In the genus *Cyrena* (fig. 619) the shell is thick, and rounded or subtrigonal, the beaks being commonly eroded. The hinge in each valve has three cardinal teeth, and a single lateral tooth in front and behind. The forms which are included under the name of *Corbicula* differ from *Cyrena* proper principally in the fact that the lateral teeth are elongated and are transversely striated. The oldest representatives of these two types appear in the Jurassic rocks, and there are numerous living forms, the Cretaceous and Tertiary rocks having also yielded many characteristic species.



Fig. 619.—*Cyrena antiqua*. Eocene.

The genus *Sphærium* (*Cyclas*) comprises fresh-water forms in which the shell is of small size, thin, more or less orbicular, and nearly equilateral. The right valve has one cardinal tooth, often bifid, and the left valve has two. The genus *Pisidium* differs from the preceding in little except that the shell is inequilateral, the anterior side being the longest. Both these types are now in existence, and the earliest fossil forms commence in the Eocene Tertiary.

Family 5. Ungulinidæ.—In this family the mantle-lobes are free; and the foot is long and vermiform, and does not secrete a byssus. The

shell is equivalve, slightly inequilateral, orbicular in form, and more or less tumid. The hinge has usually two cardinal teeth in each valve, without lateral teeth. The ligament is wholly or partially internal, and the pallial line is entire.

The type-genus of this little group is *Ungulina*, which is represented by living species and by a few Tertiary forms.

Family 6. Unicardiidæ. — In this family the shell is equivalve, slightly inequilateral, oval or rounded, and concentrically striated. The hinge carries a single cardinal tooth in each valve ; the ligament is lodged in an external marginal groove ; the adductor impressions are elliptical ; and the pallial line is entire. The genus *Unicardium* is the type of this family, and its species range from the Trias to the Chalk. Fischer also includes here his genus *Pseudedmondia*, of the Carboniferous rocks, founded for the reception of certain forms of *Edmondia* in which the ligament is external, and is placed in a marginal groove.

Family 7. Tancrediidæ.—This family includes transversely triangular shells, resembling *Donax* in form, with an external ligament, and an *entire* pallial line. The hinge has in each valve two cardinal teeth (sometimes only a single tooth in one valve), with lateral teeth as well, at any rate posteriorly. The type of this family is the extinct genus *Tancredia*, in which the shell is attenuated in front, and obliquely truncated behind. The species of this genus range from the Trias to the Chalk.

Family 8. Donacidæ.—In this family the animal is marine or estuarine in habit, with a large foot, and short separate siphons. The shell is equivalve, more or less wedge-shaped, close, and non-nacreous. The hinge carries one or two cardinal teeth in each valve, with inconstant lateral teeth ; the ligament is external ; and the pallial line is deeply indented.



Fig 620. — Interior of the right valve of *Donax retusa*. Eocene.

In the genus *Donax* (fig. 620), the shell is wedge-shaped, the front rounded and produced, and the posterior side short and obliquely truncated. There are numerous living species of this genus, and a small number of fossil forms, the oldest undoubted types appearing in the Eocene deposits. The Jurassic genus *Isodonta* (*Sowerbya*) may be placed in the neighbourhood of *Donax*.

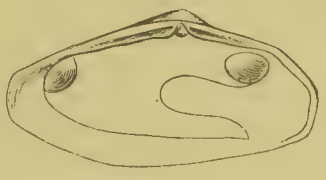


Fig. 621.—Interior of the right valve of *Psammobia rudis*. Eocene.

Family 9. Psammobiidæ.—This family includes marine Bivalves, with long separate siphons and a tongue-shaped foot. The shell is transversely elongated, equivalve, sub-equilateral, slightly gaping at both ends, with an external ligament, and a deeply sinuated pallial line (fig. 621). The hinge usually carries two cardinal teeth in each valve, but there are no lateral teeth.

The type of this family is the genus *Psammobia*, in which the

shell is oblong, compressed, and nearly equilateral (fig. 621). There are many recent species of this genus, together with a moderate number of Tertiary forms, but the earliest appearance of the genus seems to be in the Cretaceous rocks. The Jurassic genus *Quenstedtia* appears to be nearly allied to *Psammobia*.

Family 10. Solenidæ.—In this family respiratory siphons are present, and are usually short and more or less united, but may be longer and separate. The foot is very large, and more or less cylindrical in shape; and the branchiæ are prolonged into the branchial siphon. The shell is transversely elongated, more or less gaping at both ends, equivalve, and covered with epidermis. The hinge is variable, carrying from one to three cardinal teeth in each valve, without lateral teeth. The ligament is external, and the pallial line is more or less sinuated. The recent members of this family are all marine or estuarine in habit, and the group attains its maximum development at the present day.

Of the genera of this family, *Solecurtus* (fig. 622) has an elongated shell with subcentral beaks, the dorsal and ventral margins being

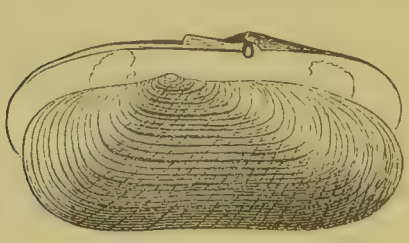


Fig. 622.—*Solecurtus Deshayesi*. Eocene. (After Zittel.)

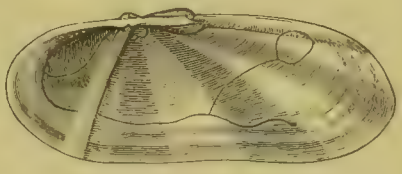


Fig. 623.—Interior of the right valve of *Siliqua polita*. Recent.

nearly parallel, and the surface generally marked with oblique lines. The genus begins in the Cretaceous rocks and still survives. In the genus *Siliqua* (fig. 623) the shell agrees in form with that of *Solecurtus*, and also has the beaks placed a little in front of the centre, but an oblique internal rib runs from below the beak to the ventral margin. This genus ranges in time, as does the preceding, from the Cretaceous to the present day. *Cultellus*, ranging from the Eocene to the present day, resembles the preceding in most characters, but the beaks are placed very far forwards, and the shell thus becomes very inequilateral. In the genera *Ensis* and *Solen* are included the typical "Razor-shells," in which the shell is greatly elongated, with the beaks placed almost at the anterior end of the shell, and with both extremities widely gaping. *Ensis* begins in the Tertiary rocks and is represented at the present day, its chief distinction from *Solen* being that the shell is somewhat curved, whereas in the latter it is straight. *Solen* itself is said to occur in deposits as old as the Devonian, but the earliest undoubted species are found in the

Trias, and the genus still survives. The Carboniferous genus *Solenopsis*, with prominent beaks and a closed anterior end, and the Devonian *Palæosolen* may represent ancient types of the *Solenidæ*. Here also, perhaps, may be placed the Palæozoic genus *Orthonota*, the typical forms of which are Devonian, though species have been described from rocks as old as the Ordovician (fig. 624). In this genus the shell is greatly elongated and very inequilateral, the anterior end being rounded and the posterior end truncate, and the beaks being close to the anterior end. The muscular impressions and pallial line have not been made out; and the hinge is only imperfectly known, but is apparently edentulous. The hinge-line is straight, and in the typical forms of the genus is continued in a straight line in front of the beaks. In one group of forms, however, sometimes distinguished under the name of *Orthodesma*, the hinge-line is bent or contracted in front of the beaks, and is straight behind (fig. 624).



Fig. 624.—*Orthonota* (*Orthodesma*) *parallela*. Ordovician.

Order X. Myacea.

In this order the mantle-lobes are united, a pedal aperture existing in front and two siphons behind. The siphons are long, and may be united or separate. The foot may or may not be byssiferous, and there are two adductor muscles. The shell is free, equivalve or inequivalve, with an internal or external ligament, and a variable pallial line, while the characters of the hinge also differ in different families of the order. The chief families of this order are the *Mactridæ*, *Myidæ*, *Glycimeridæ*, and *Gastrochænidæ*.

Family 1. Mactridæ.—In this family the mantle is more or less open in front; the siphons are united, with fringed orifices; and the foot is compressed. The shell is equivalve, trigonal, generally gaping behind; the ligament being typically internal and lodged in a deep triangular pit between the beaks. The left valve has a widely bifurcated cardinal tooth, which is received between the diverging branches of a right cardinal tooth; and lateral teeth are usually present in addition in front and behind. The pallial line is usually deeply sinuated. The members of this family are all marine, and the two principal genera are *Mactra* and *Lutraria*.

In the genus *Mactra* (fig. 625) the shell is trigonal in form, slightly gaping behind, with a short pallial sinus. The internal ligament is contained in a triangular pit, but there is also an external ligament lodged in a groove. The recent species of

Mactra live buried in sand or mud. The fossil forms begin in the Jurassic rocks, but the genus does not show any extensive development till the Tertiary rocks are reached.

In the genus *Lutraria* the shell is oblong and gaping at both ends; the pallial sinus is deep, and the internal ligament is supported by a prominent, spoon shaped cartilage-plate. The earliest undoubted fossil forms of this genus appear in the Tertiary rocks, and about thirty living species are known.



Fig. 625.—*Mactra podolica*. Miocene Tertiary, Austria. (After Zittel.)

Family 2. Myidæ.—In this family the mantle is almost entirely closed, but there exists in front an aperture for the small triangular foot, while posteriorly are two long siphons, more or less completely united with one another (fig. 555), and partly or wholly retractile. The shell is inequivalve, thick, gaping posteriorly, and not nacreous internally. The internal ligament is supported upon a spoon-shaped process developed from the hinge-plate of the left valve. The members of this family are marine or estuarine in habit, and the principal genera are *Mya*, *Corbula*, and *Neæra*.

In the genus *Mya* the shell is oblong, inequivalve, and gaping at both ends. The left valve is the smallest, and it carries an internal ligament supported upon a prominent cartilage-process (figs. 626, 627). The Myas live buried vertically in sand or mud. They are not known to have existed before the period of the Middle Tertiary (Miocene), and almost all the fossil species are in existence at the present day.



Fig. 626.—*Mya truncata*. Post-Pliocene and Recent.



Fig. 627.—Portion of the hinge of *Mya arenaria*, showing the cartilage-process.

In *Corbula* (fig. 628) the shell is inequivalve, the left valve the smallest, and with a prominent cartilage-process; but the shell is

gibbous, and does not gape at its ends, whilst the pallial sinus is small. The recent species of *Corbula* live partly in the sea, and partly in estuaries or at the mouths of rivers. There are numerous fossil forms of the genus, especially in the Cretaceous and Tertiary rocks; but the oldest forms appear in the Trias.

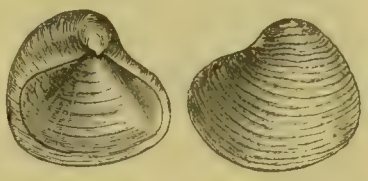


Fig. 628.—*Corbula pisum*, viewed from the left and right sides. Eocene.

The genus *Neæra* is allied to *Corbula*, but the shell is nearly equivalve, the right valve being slightly the smallest, and the shell is produced and open posteriorly. The earliest types of *Neæra* appear in the Upper Jurassic rocks, and the genus still survives.

Family 3. Glycimeridæ.—In this family the mantle-lobes are united, and there are long siphons, which are united wholly or in great part. The shell is equivalve or nearly so, gaping at both ends, and covered with a thick epidermis, which is prolonged over the siphons. The hinge has one or two weak cardinal teeth, or is toothless. The ligament is external, and the pallial sinus varies in depth. The Bivalves included in this family are all marine, and are either free or burrow in mud.

In *Glycimeris* (= *Panopæa*) the shell (fig. 629, A) is thick, oblong, inequilateral, and gaping at both ends. A single cardinal tooth is

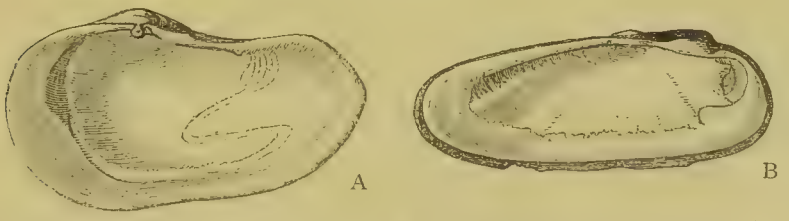


Fig. 629.—A, Interior of the right valve of *Glycimeris* (*Panopæa*) *Americana*, from the Miocene rocks of North America, one-third of the natural size; B, Interior of the left valve of *Cyrtodaria* (*Glycimeris*) *siliqua*, Arctic seas, two-thirds of the natural size. (After Woodward.)

present in each valve; the pallial line is continuous, and the pallial sinus is very deep. Several Recent species of *Glycimeris* are known, and there are also various Tertiary forms, the earliest types of the genus seeming to occur in the Cretaceous rocks. Allied to the preceding is the genus *Cyrtodaria* (= the *Glycimeris* of many authors). in which the shell agrees generally with that of *Glycimeris*, but the pallial line is interrupted, and the pallial sinus is very slight (fig. 629, B).

In the genus *Saxicava* (fig. 630) the animal burrows in rocks, or fixes itself in crevices by means of a byssus. The adult shell is

thick and oblong, more or less inequivalve, irregular, and often gaping. The hinge is generally edentulous, and the pallial line is interrupted. The genus seems to commence in the Eocene Tertiary, and has continued to the present day.

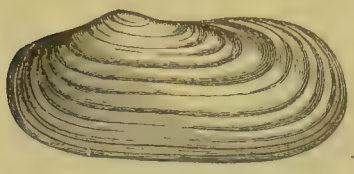


Fig. 630.—*Saxicava rugosa*, left valve. Post-Pliocene and Recent.

Family 4. Gastrochænidæ.—In this family the mantle-lobes are united; there are long siphons, joined together; and the foot is of small size, finger-shaped, and not byssiferous. The shell is equivalve, inequilateral, thin, wedge-shaped, and gaping in front. The beaks are placed anteriorly, and the anterior side of the shell is short. The hinge is toothless; the ligament is external; and the pallial sinus is deep. The members of this family burrow in rocks, corals, &c., or bury themselves in mud; and a longer or shorter shelly tube, to which the shell itself is commonly cemented, is often developed. The tubes and shells of *Gastrochæna* are not very rarely found in the fossil state in rocks of Secondary and Tertiary age, and a number of living species are known. The allied genus *Fistularia* ranges from the Cretaceous rocks to the present day.

Order XI. Adesmacea.

In this order the mantle-lobes are united, and there are long siphons joined along almost their entire length. The foot is generally well developed, and there are two adductor muscles. The shell consists essentially of two valves, but accessory plates or an adventitious calcareous tube may be developed in addition. A portion of the cardinal margin is reflected above the beaks, and the umbonal cavity is divided internally by a prominent process. The hinge and ligament are not developed. The members of this order are inhabitants of the sea or of brackish waters, and they all form perforations in stone or wood. The order is divided by Fischer into the two closely related families of the *Pholadidæ* and *Teredinidæ*.

Family 1. Pholadidæ.—In this family the animal is club-shaped or worm-like, with a short truncated foot, and long siphons united to near their extremities. The shell is gaping at both ends, with a portion of the cardinal margin reflected over the beaks, and usually having the dorsal region protected by one or more accessory plates. The members of this family are almost exclusively marine, and form burrows in stone or wood. In some cases (as in *Pholas* itself) the young are similar to the adult; whereas in other cases (*Pholadidea*, *Teredina*, &c.) a marked metamorphosis takes place in development. This metamorphosis consists essentially in the formation of a cal-

careous plate which fills up the anterior vacuity in the valves, and in the production from the hinder end of the shell of cup-shaped appendices which may coalesce to form a longer or shorter tube.

In the genus *Pholas*, the shell is cylindrical or oval, and the front portion of the valves is marked with conspicuous radiating ridges or rows of spines. The valves are edentulous; and there is no ligament, or a rudimentary one. The pallial sinus is very deep, and the dorsal margin of the shell is protected by accessory valves. The *Pholades* inhabit burrows which they form for themselves in clay, peat, or rock, and they are known in the fossil condition not only by their shells but also by their burrows, the latter affording useful indications of the existence of old shore-lines. Various extinct forms are known from the Tertiary rocks, and the genus appears to be represented in the Cretaceous and Jurassic deposits.

In the recent genus *Pholadidea* the shell has a transverse furrow, and the anterior vacuity of the valves becomes filled up with a callous plate. In the genus, or sub-genus, *Parapholas*, again, the anterior aperture becomes similarly closed by a callous plate, but the valves show two oblique furrows running from the beaks to the ventral margin (fig. 631).

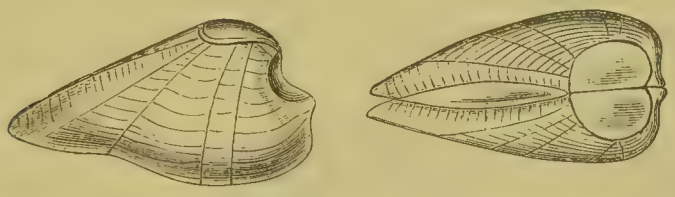


Fig. 631.—*Parapholas mersa*, viewed from one side and above. Cretaceous. (After Stoliczka.)

The species of *Parapholas* range from the Cretaceous rocks to the present day. In the allied *Martesia* the anterior vacuity is also closed by a callous plate, and the beaks are covered by a simple shield-like lamina. The living species of *Martesia* burrow in wood, and the earliest fossil forms have been detected in the Carboniferous rocks. The recent genus *Xylophaga* also comprises wood-boring forms, and is represented in rocks as ancient as the Jurassic and Cretaceous by allied types (*Xylophagella*). Lastly, Fischer places in this family the Eocene genus *Teredina*, in which there is a globular shell, the anterior vacuity of which is closed by a callous plate, while the beaks are covered by a dorsal plate, and the valves are fused with a long calcareous tube, developed posteriorly.

Family 2. Teredinidæ.—This family includes only the single genus *Teredo*, the characters of which are, therefore, those of the family. In *Teredo*, the shell is "globular, open in front and behind, lodged at the inner extremity of a burrow partly or entirely lined by shell; valves three-lobed, concentrically striated, and with one transverse furrow; hinge-margins reflected in front, marked by the anterior muscular impressions; umbonal cavity with a long curved muscular

process" (Woodward). Species of *Teredo* occasionally reach a very large size, and they are known in the fossil state both by their shells and by their burrows in wood. The genus seems to have commenced in the Lias, and is well represented at the present day. Numerous Tertiary species are known, but the recognition of the existence of the "Ship-worms" in past time very generally depends simply upon the presence of their filled-up burrows in fossil wood.

Order XII. Lucinacea.

This order includes marine Lamellibranchs, with typically but a single branchia on each side and with two adductor muscles, the mantle-lobes being more or less free, and the foot usually vermiform. The shell is free, non-nacreous, the hinge with cardinal and lateral teeth, and the pallial line entire. The only family included in this order is that of the *Lucinidæ*, the precise limits of which, as regards fossil forms more particularly, are still uncertain.

Family 1. Lucinidæ.—The mantle-lobes in this family are open below, with one or two siphonal apertures behind, and the foot is elongated, cylindrical, or strap-shaped. The shell is orbicular and free, with one or two cardinal teeth, and generally a single lateral tooth on each side. The ligament is partially or wholly internal, or

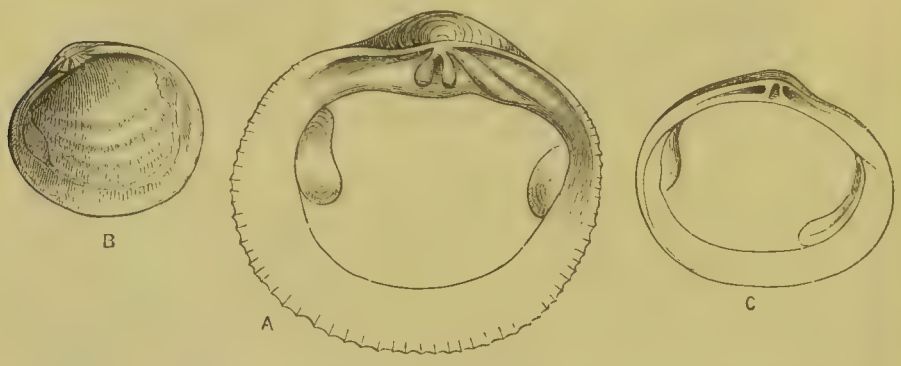


Fig. 632.—A, Interior of the right valve of *Corbis pectunculus*—Eocene; B, Interior of the right valve of *Diplodonta lupinus*—Miocene; C, Interior of the left valve of *Lucina striatula*—Jurassic.

in some cases (*Diplodonta*) external. The anterior adductor impression is usually elongated. Taken as a whole, the family is principally Secondary, Tertiary, and Recent, its Palæozoic representatives being mostly imperfectly understood, and referred here with doubt. In *Lucina* itself, the type of the family (fig. 632, C), the shell is rounded, with a lunule beneath the beak; the ligament is in a deep groove, sometimes nearly or quite internal; and the teeth have the typical arrangement of the entire group, though some are occasion-

ally obsolete. Little can be said with certainty as to the Palæozoic shells usually referred to *Lucina*, but the genus is abundantly represented in Secondary and Tertiary deposits; and ancient representatives of the genus have been described from the Silurian and Devonian rocks. *Corbis* (fig. 632, A), with many species from the Trias onwards, is very like *Lucina*, but has the surface concentrically furrowed, with denticulate edges. *Diplodonta* (Cretaceous to Recent) has two cardinal teeth in each valve, the anterior in the right and the posterior in the left being bifid (fig. 632, B). Lastly, the genus *Axinus* of Sowerby may perhaps be referred here, though the hinge is toothless or has only a feeble tooth in the right valve. The range of this genus is from the Eocene to the present day.

Order XIII. Tellinacea.

In this order the foot is very large; there are two adductor muscles; there is only a single gill on each side; and the siphons are long and completely separate. The shell is free, non-nacreous, the hinge with cardinal and lateral teeth, and the pallial line deeply sinuated. This order includes the two families of the *Tellinidæ* and *Scrobiculariidæ*, all the members of which are marine in habit.

Family 1. Tellinidæ.—In this family the shell is free, usually equivalve and closed, with smooth margins. The hinge has at most two cardinal teeth in each valve, with a lateral tooth on each side, or without lateral teeth. The ligament is external, and the pallial sinus is very deep.

The principal genus in this family is *Tellina* itself, which includes about three hundred living species and a considerable number of fossil forms, mostly from the Tertiary rocks. In this genus the shell is oval or transversely elongated, very slightly inequivalve, the anterior side being rounded, and the posterior side often angulated. The beaks are often placed nearly in the middle of the shell; the ligament is prominent and external; and the pallial sinus is very broad and deep. The oldest undoubted forms of *Tellina* appear in the Lower Cretaceous rocks.

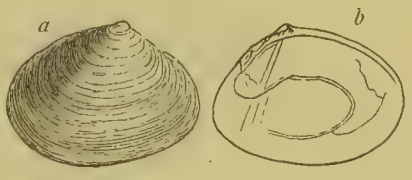


Fig. 633.—*Tellina proxima*, right valve. Post-Pliocene.

Family 2. Scrobiculariidæ.—In this family the animal agrees with that of *Tellina* in general structure, and the characters of the shell are in most respects the same; but the ligament is internal, and is lodged in a pit below the beaks, an external ligament being sometimes imperfectly developed as well. The two principal genera

are *Scrobicularia* and *Semele*, both of which are represented by Tertiary and Recent species.

Order XIV. Anatinacea.

This order includes marine Bivalves with a moderate-sized, grooved, or byssiferous foot, distinct siphonal orifices, a single branchia on each side, and two adductor muscles. The shell is thin, usually with a pearly internal layer and a finely granulated external layer. The hinge may or may not carry teeth, and the pallial line is mostly sinuated, but may be entire. The principal families included in this order are the *Solemyidæ*, *Arcomyidæ*, *Anatinidæ*, *Grammysiidæ*, *Præcardiidæ*, *Pholadomyidæ*, and *Clavagellidæ*.

Family 1. Solemyidæ.—This family includes the single genus *Solemya*, which ranges from the Devonian to the present day. In this genus the shell is equivalve, inequilateral, transversely elongated, obtuse and gaping at both ends, with the epidermis prolonged beyond the ventral margin. The beaks are inconspicuous; the ligament is partly internal and partly external; the hinge is toothless, or has a single cardinal tooth in each valve; and the pallial line is obscure. The Devonian and Carboniferous genus *Clinopistha* appears to be related to *Solemya*.

Family 2. Arcomyidæ.—The forms included in this family are all extinct, and have usually been included in the *Pholadomyidæ*, from which they are distinguished by the finely granulated character of the exterior of the shell. The shell is equivalve, inequilateral,



Fig. 634.—*Arcomya* (*Homomya*) *calceiformis*, viewed from the dorsal side, two-thirds of the natural size. Lower Jurassic rocks. (After Zittel.)

very thin, with an edentulous hinge, but with a thickened cardinal margin. The ligament is external and prominent, and the pallial line is sinuated. The principal genera included in this family are *Arcomya* (fig. 634), *Goniomya*, and *Pleuromya*, all of which are confined to the Secondary rocks, the first and last ranging from the Trias to the Chalk, while *Goniomya* is Jurassic and Cretaceous.

Family 3. Anatinidæ.—In this family the mantle-lobes are more

or less united; there are long siphons, more or less extensively conjoined, and the foot is of small size. The shell is thin, usually nacreous internally, and commonly granulated externally, and as a rule somewhat inequivalve. The ligament is wholly or partially internal, usually in a spoon-shaped cartilage-pit, flanked by one or two cardinal teeth, and often containing a detached ossicle. The pallial line is usually sinuated. All the members of this family are inhabitants of the sea.

In *Anatina* itself (fig. 635) the shell is oblong, very thin, gaping behind, and having the beaks turned towards the posterior side of the shell, which is more or less attenuated. The hinge of each valve carries a spoon-shaped cartilage-process, and the beak is usually supported by an oblique, backwardly directed internal ridge. The pallial line is deeply sinuated. The earliest undoubted forms of *Anatina* are found in the Lower Cretaceous rocks, and the genus survives at the present day. The genus *Thracia*, ranging from the Trias to the present day, is in most respects very similar to *Anatina*, but the shell is inequivalve (the right valve being larger than the left), and there is a short external ligament, in addition to the internal cartilage. In *Pandora* the shell is also thin and inequivalve, but it does not gape behind. The species of this genus range from the Eocene to the present day; and the species of the allied genus *Lyonsia* have a similar range in time. Lastly, the Cretaceous genus *Liopistha* appears to belong here, though the pallial line is apparently not sinuated. Numerous Palæozoic Bivalves have been referred to the *Anatinidæ*, but most of these are characterised by an entire pallial line and an external ligament, and may be provisionally placed in the family of the *Grammysiidæ*. It is possible, however, that the genus *Allorisma* (fig. 636, c) should find a place in the *Anatinidæ*, with which it agrees in the possession of a sinuated pallial line, and in having the external surface of the valves granulated. The shell in this genus is transversely elongated, equivalve, with anteriorly-placed, almost terminal beaks, and a concentrically-striated surface. The hinge is edentulous, and an external ligament is present. The species of *Allorisma* range from the Devonian to the Permian rocks.

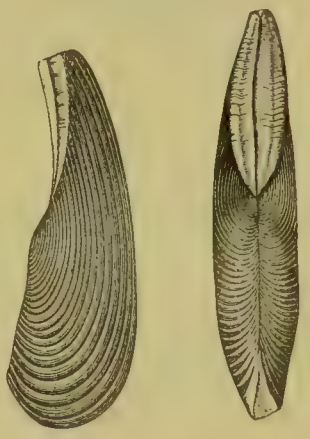


Fig. 635.—*Anatina spatulata.*
Kimeridge Clay (Upper Oolites.)

Family 4. Grammysiidæ.—This family comprises a number of Palæozoic Bivalves which differ from the typical *Anatinidæ* in having an entire pallial line, and also in the fact that the ligament is

external. The shell in the forms included here is equivalve, oval or transversely elongated, convex, and thin. The hinge is edentulous, and the cardinal border is straight. Fischer regards this family as representing in the Palæozoic deposits the *Arcomyidæ* of the Secondary period, but the affinities of most of the genera provisionally associated with *Grammysia* must be regarded as very uncertain.

In the Silurian and Devonian genus *Grammysia* (fig. 636, B) the shell is transversely elongated, equivalve, with the beaks placed very

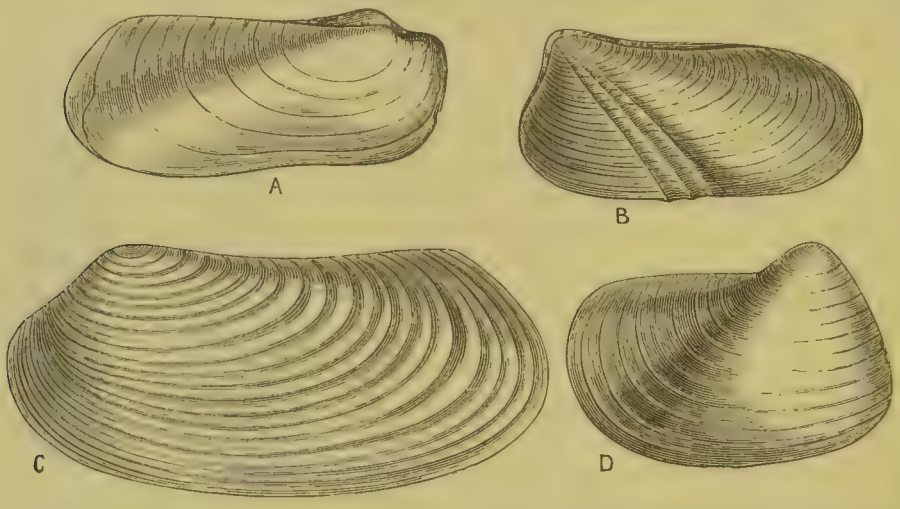


Fig. 636.—A, Right side of *Palæanatina typa*, showing the superior size of the left beak—Devonian (after Hall); B, *Grammysia cingulata*—Silurian; C, *Allorisma sulcata*—Carboniferous (after Phillips); D, *Leptodomus truncatus*—Silurian (after M'Coy).

far forwards and incurved, a deep "lunule" being present below them. The hinge-line is straight, and the hinge is edentulous; and a single or double fold extends backwards from the beaks to the middle of the ventral margin.

The following Palæozoic genera agree with *Grammysia* in more or fewer characters, and may be provisionally associated with it, though they diverge in important respects from the above general definition of the family *Grammysiidæ*. In *Cardiomorpha* (Silurian to Carboniferous) the shell is shaped like that of *Isocardia*, with approximated, almost terminal beaks, and a simple pallial line. The hinge is toothless, and there is an elongated groove for the external ligament. In the genus *Leptodomus*, with a similar geological range to the preceding, the shell (fig. 636, D) is thin and elongated, with tumid incurved beaks, a well-marked posterior slope, and a deep "lunule." The hinge is toothless, and the surface is marked with concentric ridges which split anteriorly. The widely distributed Carboniferous genus *Edmondia* has "a transversely-oval, equivalve, edentulous shell, with an internal lamellar cartilage-support. The dorsal margins are erect and simple, and the pallial line is entire" (R. Etheridge, jun.) In the genus *Sanguinolites*, principally if not exclusively Carboniferous in its range, the shell is "transversely oblong and

equivalve, but very inequilateral, possessing an external ligament, and a strong external oblique posterior ridge, the pallial line being entire" (R. Etheridge, jun.) The Carboniferous genus *Anthracomya*, in which there is a thin concentrically-striated oblong shell, with anterior beaks and an external ligament, may perhaps also find a place here. The Devonian genus *Palæanatina* (fig. 636, A) more probably belongs to the *Anatinidæ*, since the shell is inequivalve (the left valve being larger than the right), and there are indications of the presence of an internal ligament; but the form of the pallial line has not been clearly ascertained. The Devonian genus *Cimitaria* also occupies an uncertain position; and there are various other Palæozoic types which may possibly be referable to this family, but which cannot be discussed here.

Family 5. Præcardiidæ.—This family has been constituted by Hoernes for the reception of a number of Silurian Bivalves, of which the genus *Præcardium* is the type. The forms here in question have thin equivalve or inequivalve shells, which have a marked general resemblance to the Cockles, but which are without the characteristic teeth of the *Cardiidæ*—the hinge being, in fact, edentulous, or furnished with transverse folds. The adductor impressions and pallial line in *Præcardium* and its allies are unknown; but Fischer suggests that the genus *Cardiola* may possibly be found to belong to this singular group.

Family 6. Pholadomyidæ.—In this family the mantle-lobes are united; and there are very long siphons, conjoined along their entire length. The foot is small, and a single gill is present on each side. The shell is equivalve, inequilateral, thin, convex, adorned with radiating ribs, pearly internally, but not granulated externally. The hinge is toothless; the ligament is external; and the pallial line is sinuated. This family has close relationships with the *Arcomyidæ* and also with the *Anatinidæ*, and the only genus included in it by Fischer is *Pholadomya* itself, which is extremely abundant in the Jurassic, Cretaceous, and Tertiary rocks, but is only known at the present day to be represented by two or three species, all of which inhabit great depths in the sea.

In *Pholadomya* (fig. 637) the shell is equivalve, oblong, and gaping posteriorly, thin, ventricose, and adorned with radiating ribs on the sides. The anterior side of the shell is short and rounded, and the beaks are prominent. The hinge is toothless, and the cardinal margin behind the beaks is often folded in so as to give rise to an elongated false area or escutcheon.



Fig. 637.—*Pholadomya æquivalvis.* Chalk.

Family 7. Clavagellidæ.—In this family the mantle-lobes are

united, and there are long conjoined siphons, with a single branchia on each side. The shell is in the young state similar to that of *Thracia*, but one or both of the valves ultimately become fused with a secondarily-produced adventitious calcareous tube, of considerable size (fig. 638).

The genus *Clavagella* itself comprises forms which burrow in rocks, corals, &c., and in which the shell is inequivalve, the left valve being fused with a long calcareous tube (fig. 638), while the right valve lies freely in the interior of the tube, the latter being often divided by a longitudinal partition. This singular genus is known to have existed in rocks as old as the Cretaceous, and still survives. In the nearly allied genus *Aspergillum* (Pliocene and Recent), both the valves of the shell are fused with the calcareous tube, which is closed below by a perforated disc with a minute central fissure.



Fig. 638.—*Clavagella cretacea.* Chalk.

CHAPTER XXXVII.

Class II. Gastropoda (or Gasteropoda).

The members of this class are *Mollusca with a more or less distinct head, and a generally unsymmetrical body. The mantle is never divided into two lobes, and the shell, when present, is univalve. The "foot" is well developed, and usually has the form of a broad horizontally-flattened ventral disc, upon which the animal creeps.*

The body in the Gastropods is composed of three principal portions—a head, foot, and visceral sac—the last of these being more or less completely protected by a fold of the dorsal integument, constituting the "mantle." The body is distinctly unsymmetrical, and the mantle is never divided into a right and left lobe, while the visceral sac is often coiled up spirally. The foot is typically in the form of a broad flattened muscular disc, developed upon the ventral surface of the body, and not exhibiting any distinct division into parts. In the *Heteropoda*, however, and in the Wing-shells (*Strombidæ*), the foot exhibits a division into three portions: an anterior, the "propodium"; a middle, the "mesopodium"; and a posterior lobe, or "metapodium." In the *Heteropoda*, the foot is flattened, and forms a ventral fin, by means of which the animal swims, back-downwards.

In some, again, the upper and lateral surfaces of the foot are expanded into muscular side-lobes, which are called "epipodia." In the Pteropodous division of the Gastropods the epipodia are the only portions of the foot which are developed, and they constitute a pair of fins attached to the sides of the head. In many cases the metapodium, or posterior portion of the foot, secretes a calcareous, horny, or fibrous plate, which is called the "operculum" (fig. 639, *o*), and which serves to close the orifice of the shell when the animal is retracted within it.

The *shell* of the Gastropods is a secretion from the mantle, and is always present in the embryo. It is, however, wanting in the adults of the Nudibranchs and in some other forms, and it is in other

cases very minute, and hidden in the mantle (as, for example, in the Slugs). From the very general occurrence of a shell which is "univalve," or composed of a single piece, the Gastropods are commonly spoken of as the "Univalve Molluscs." In its chemical composition the shell is composed of carbonate of lime (sometimes in the condition of calcite, sometimes in that of aragonite). Its inner layer is often nacreous, and it grows by additions made to its free margin by the muscular edge ("collar") of the mantle, in which



Fig. 639.—*Ampullaria canaliculata.* *o*, Operculum; *s*, Respiratory siphon.

numerous pigment-glands are contained. Primitively the shell is covered with a horny cuticular layer ("epidermis"), but this often disappears with age. In many cases, the mantle becomes reflected over the shell, the outer surface of which may thus become covered with a layer of enamel (as in the Cowries).

The shell of the Gastropods is to be regarded as essentially a cone, the apex of which is more or less oblique. In the simplest form of the shell, the conical shape is retained without any alteration, as is seen in the common Limpet (*Patella*). In the great majority of cases, however, the cone is considerably elongated, so as to form a tube, which is usually coiled up into a spiral. The "spiral univalve" (fig. 640) may, in fact, be looked upon as the typical form of the shell in the *Gastropoda*. In some cases the coils of the shell—termed technically the "whorls"—are hardly in contact with one another (as in *Vermetus*). More commonly the whorls are in contact, and are so amalgamated that the inner side of each convolution is formed by the pre-existing whorl. In some cases the whorls of the shell are coiled round a central axis *in the same plane*, when the shell is said to be "discoidal" (as in the common fresh-water shell *Planorbis*). In most cases, however, the whorls are wound round an axis in an oblique manner, a true spiral being formed, and the shell becoming "turreted," "tro-

choid," "turbinated," &c. This last form is the one which may be looked upon as most characteristic of the Gastropods, the shell being composed of a number of whorls (fig. 640, *wh*) passing obliquely round a central axis or "columella" (*co*), having the embryonic shell or "nucleus" at its apex (*a*), and having the mouth or "aperture" of the shell placed at the extremity of the last and largest of the whorls, termed the "body-whorl" (*wh'*). The lines or grooves formed by the junction of the whorls are termed the "sutures" (*su*), and the whorls above the body-whorl constitute the "spire" (s) of the shell. The axis of the shell (columella), round which the whorls are coiled, is usually solid, when the shell is said to be "imperforate"; but it is sometimes hollow, when the shell is said to be "perforated," and the aperture of the axis near the mouth of the shell is called the "umbilicus." The margin of the "aperture" of the shell is termed the "peristome," or "peritreme," and is composed of an outer and inner lip, of which the former (fig. 640, L) is often expanded or fringed with spines. When these expansions or fringes are periodically formed, the place of the mouth of the shell at different stages of its growth is marked by ridges or rows of spines, which cross the whorls, and are called "varices." In certain groups of the Gastropods (*Holostomata*) the aperture of the shell is unbrokenly round or "entire," but in other groups (*Siphonostomata*) it is notched, or produced into a canal. Often there are two of these canals, an anterior and a posterior, and the function of these is to protect the respiratory siphons. The animal withdraws into its shell by a retractor muscle, which passes into the foot, or is attached to the operculum; its scar or impression being placed, in the spiral Univalves, upon the columella. In the great majority of the Univalves the shell is coiled to the left, the "mouth" of the shell being thus on the right-hand side (fig. 640). In such cases the shell is said to be right-handed or "dextral." In other cases, however, the shell is coiled to the right, and the mouth

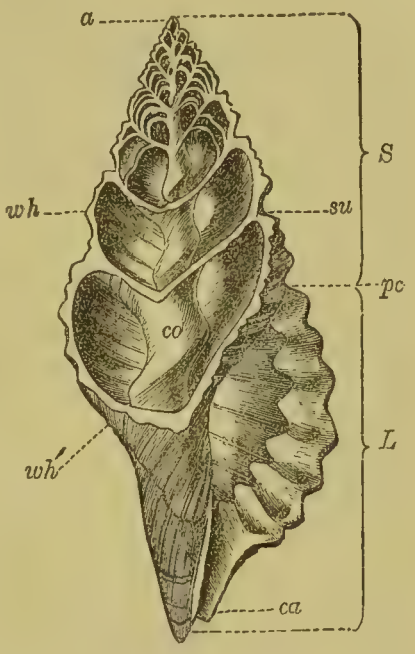


Fig. 640.—Longitudinal section of *Triton corrugatum*. S, Spire; L, Outer lip of the aperture of the shell; *a*, Apex; *wh*, The last whorl of the spire; *wh'*, The body-whorl; *su*, Suture; *ca*, Anterior canal; *pc*, Posterior canal.

is on the left, when the shell becomes "reversed" or "sinistral." The left-handed spiral may be the normal condition of the shell, or it may be only a variety of a normally dextral form.

As regards their internal anatomy, the head of the Gastropods is usually very distinctly marked out, and is generally provided with tentacles and eyes. Within the pharynx is found the singular dental apparatus which is known as the "odontophore." The essential portion of this is a chitinous band, which is beset with minute transversely-arranged teeth, and is known as the "radula" or "lingual ribbon." The radula is supported upon a cartilaginous cushion, which can be made to rotate by special muscles, the ribbon thus coming to act as a file, rasp, or chain-saw. The arrangement of the teeth in the radula varies much in different cases, but they are usually disposed in a median series, flanked by two or more lateral rows; and their form and disposition are so constant as to afford one of the most valuable aids to the classification of the recent *Gastropoda*. As, however, the characters of the radula cannot be determined in the case of fossil Gastropods, a classification based upon the structure of this organ is necessarily defective from a palæontological point of view.

Respiration in the Gastropods is variously effected; the members of one great section (*Branchiogastropoda*) being, with few exceptions, constructed to breathe air dissolved in water, while in another division (*Pulmogastropoda*) the respiration is aerial. In the former division, respiration may be effected in several ways. Firstly, there may be no specialised respiratory organ, the blood being simply exposed to the water in the thin walls of the mantle-cavity (as in some of the *Heteropoda*). Secondly, the respiratory organs may be in the form of outward processes of the integument, exposed in tufts on the back and sides of the animal (as in the *Nudibranchiata*). Thirdly, the respiratory organs are in the form of pectinated or plume-like branchiæ, contained in a more or less complete branchial chamber formed by an inflection of the mantle. In many members of this last section the water obtains access to the gills by means of a tubular prolongation or folding of the mantle, forming a "siphon" (fig. 639, *s*), the effete water being expelled by another posterior siphon similarly constructed. The number of gill-plumes differs in different groups. In most cases there is only a single branchial plume, placed on the right side of the neck; in other cases an additional gill is present on the left side; and in other forms, again (*e.g.*, *Patella*), the gills are multiple and are arranged in a circle. Lastly, in the Pulmonate Gastropods the breathing-organ is a pulmonary chamber, formed by an inflection of the mantle, the walls of which are richly supplied with blood, while air is admitted to its interior by a distinct aperture. A tran-

sition between the Branchiate and Pulmonate groups is effected by forms like *Ampullaria*, in which gills are present, but the walls of the mantle-cavity are in parts highly vascular, and are thus adapted for aerial respiration. Another link between these two groups is afforded by forms like the *Cyclostomidæ* and the *Helicinidæ*, in which the general organisation of the animal is that of the Prosobranchiate Gastropods, but the breathing-organ is a pulmonary chamber.

A few Gastropods retain the eggs within the uterus until they are hatched; but the majority are oviparous. The eggs are often laid in the form of a string or band ("nidamental ribbon"); or they may be enclosed in horny capsules (as, for example, in the common Whelk). The young, when first hatched, are provided with an embryonic shell, which in the adult may become concealed in a fold in the mantle, or may be entirely lost. In the common spiral Univalves the embryonic shell remains at the summit of the spire, as the "nucleus" of the adult shell. In the branchiate Gastropods the embryo is protected by a small nautiloid shell, and passes through a "veliger" stage, swimming freely by means of a ciliated, often lobed "velum." Among the Pulmonate Gastropods, those which are strictly terrestrial pass through no metamorphosis, the "velum" being absent in the embryo.

As regards their *classification*, the Gastropods may be divided into the two primary groups, or sub-classes, of the *Branchiogastropoda* and the *Pulmogastropoda*, the *general* distinction between the two divisions being that the animal in the former is adapted for an aquatic mode of respiration, while in the latter the breathing-organ is a pulmonary sac. The division of the Branchiate Gastropods may, again, be divided into the four orders of the *Prosobranchiata* (the ordinary Univalves), the *Opisthobranchiata* (the Sea-slugs), the *Pteropoda* (the Winged Snails), and the *Heteropoda;* while the Pulmonate Gastropods may be divided into the two orders of the *Stylommatophora* and *Basommatophora*, in accordance with the position of the eyes. The Chitons (*Polyplacophora*) and the *Dentaliidæ* (*Scaphopoda*), often included among the *Gastropoda*, will be here regarded as constituting two separate classes of *Mollusca*.

As regards their *distribution in space*, the Heteropods, the Pteropods, the Opisthobranchiates, and the great majority of the Prosobranchiates are inhabitants of the sea. Certain groups of the Prosobranchiates, however, are found either in brackish or in fresh waters; while the terrestrial groups of the *Cyclostomidæ*, *Aciculidæ*, and *Helicinidæ*, often placed among the Pulmonate Gastropods, are now usually regarded as being essentially Prosobranchiates modified for an aerial mode of respiration. The Pteropods and the Heteropods

are oceanic in habit, and are found swimming in the open sea, near the surface, far from land; but the majority of the marine Prosobranchs and the Opisthobranchs are inhabitants of shallow seas, or live between tide-marks. In depths beyond five hundred fathoms the number of Gastropods is greatly reduced; but a few forms are found to inhabit depths of between two and three thousand fathoms, or even more. The Pulmonate Molluscs, lastly, are exclusively terrestrial in habit, or live in fresh waters. In the latter case, the animal either comes to the surface from time to time, for the purpose of obtaining air, or, if the water be too deep to allow of this, its pulmonary chamber is so far modified that it is enabled to breathe the oxygen dissolved in the surrounding water.

As regards their *distribution in time*, the Branchiate Gastropods are necessarily more largely represented as fossils than the Pulmonate forms. The record of the Prosobranchiates, owing to their possession of a calcareous shell and their aquatic habits, is a very full one. On the other hand, the Opisthobranchiates are but imperfectly represented in past time, the entire group of the Nudibranchs being unprovided with a shell, and being therefore unknown in the fossil condition. The oceanic group of the Heteropods (if the *Bellerophontidæ* be placed elsewhere) is only represented in the latest Tertiary deposits; while the Pteropods, also pelagic in habit, occur as fossils in the older Palæozoic rocks, but are singularly absent from the greater part of the Mesozoic and Kainozoic formations. Of the Pulmonate Gastropods, those forms which live habitually in fresh water (*e.g.*, the *Limnæidæ*) are naturally more largely represented in the fossil condition than the purely terrestrial forms (*e.g.*, the *Helicidæ*); but the remains of the latter are not uncommon in deposits which have been formed under suitable conditions.

The Gastropods appear for the first time in the Upper Cambrian deposits, from which a number of forms have been obtained, all belonging to the holostomatous division of the Prosobranchiates, the two principal genera being *Murchisonia* and *Pleurotomaria*. The Upper Cambrian rocks have also yielded the oldest examples of *Hyolithes* and its allies, which are usually regarded as belonging to the *Pteropoda*. In the Ordovician and Silurian rocks are found very numerous types of the Prosobranchiate Gastropods, all of which—with the apparent exception of such forms as *Subulites* and *Euchrysalis*—are holostomatous. The predominant groups in these ancient deposits are the *Euomphalidæ*, *Pleurotomariidæ*, and *Bellerophontidæ*. The Pteropods are represented by the aberrant types *Conularia*, *Hyolithes*, and *Tentaculites*. In the Devonian, Carboniferous, and Permian formations the general character of the Gastropodous fauna undergoes little change, the predominating

forms still belonging to the holostomatous Prosobranchiates and the Pteropods. The latter, however, are now in part represented by such normal forms as *Styliola*. In the Carboniferous rocks, further, appear the first representatives of the Pulmonate Gastropods (*Zonites*, *Physa*, &c.)

In the Trias the Gastropodous fauna has, in the main, a Palæozoic facies, but unquestionable siphonostomatous Prosobranchiates appear here (*Cerithium*, *Purpurina*, &c.) The peculiar Palæozoic Pteropods (with the exception of *Conularia*) have now disappeared. In the Jurassic rocks a further change occurs, and a marked development of the siphonostomatous Prosobranchiates now takes place. The first Opisthobranchs appear at this stage, and we meet here with a number of existing genera of fresh-water Gastropods (*Planorbis*, *Paludina*, *Melania*, &c.) In the Cretaceous rocks the siphonostomatous Prosobranchiates continue to increase in number, and in the Tertiary period they become the predominant group, the Gastropods as a whole becoming at the same time the predominant group of the *Mollusca*, a condition of things which still subsists at the present day.

CHAPTER XXXVIII.

DIVISIONS OF THE GASTROPODA.

Sub-Class I. Branchiogastropoda.

This primary division of the Gastropods is distinguished, speaking generally, by the fact that the animals included in it are water-breathers, respiration being effected by the thin walls of the mantle-cavity, by external branchial tufts, or by pectinated or plume-like gills contained in a more or less complete branchial chamber. The groups of the *Cyclostomidæ*, *Aciculidæ*, and *Helicinidæ*, from the general characters of their organisation, must, however, be placed in this division; although the animal in these is terrestrial, and is furnished with a pulmonary chamber adapted for breathing air directly.

This sub-class comprises the four orders of the *Prosobranchiata*, *Opisthobranchiata*, *Pteropoda*, and *Heteropoda*.

Order I. Prosobranchiata.

The great majority of the members of this order are aquatic in habit, and possess gills situated in front of the heart, the auricle of the heart being thus placed in front of the ventricle. The *Cyclostomidæ*, *Aciculidæ*, and *Helicinidæ* alone possess a pulmonary chamber. The gills are, typically, plume-like, and are lodged in a branchial chamber formed by a fold of the mantle, which may or may not be so disposed as to form an anterior and posterior tube or "siphon," for the entrance and escape of water from the branchial chamber. The foot in the Prosobranchiates is large and adapted for creeping, and the sexes are distinct. Those members of the order which possess an anterior siphon for the admission of water to the branchial cavity, have the mouth of the shell notched in front, or produced into a canal in which the siphon is lodged (fig. 642); while a similar notch or canal may exist at the posterior end of the shell-aperture (fig. 643). The shell in these forms is said to be "siphonostomatous."

In a great many forms, on the other hand, siphons are not developed, and the mouth of the shell is simply rounded or "entire" (fig. 641), when the shell is said to be "holostomatous."

The great majority of the *Prosobranchiata* are inhabitants of the sea, but certain groups are restricted to fresh or brackish waters; while the *Cyclostomidæ*, *Aciculidæ*, and *Helicinidæ* are terrestrial in habit. As regards their distribution in time, the palæontological record is fuller in the case of the Prosobranchiates than it is in the case of any other division of the Gastropods. The Palæozoic types of the Prosobranchiates belong almost exclusively to forms in which the shell is "holostomatous." On the other hand, forms with the "siphonostomatous" type of shell-mouth do not make an undoubted



Fig. 641.—*Scalaria Grœnlandica*, a holostomatous Univalve.

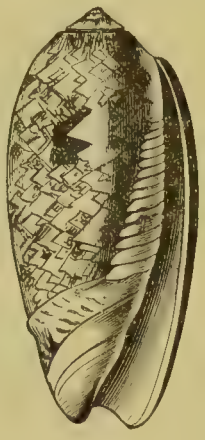


Fig. 642.—*Oliva porphyria*, a siphonostomatous Univalve.



Fig. 643.—*Cerithium aluco*, showing an anterior and posterior notch for the siphons.

appearance till the Trias is reached, and they become the predominant group of Prosobranchiates in the Tertiary rocks, which position they still hold.

The possession of a "holostomatous" or "siphonostomatous" shell has been employed as the basis for a separation of the *Prosobranchiata* into two primary sections—viz., the *Holostomata* and *Siphonostomata*—but these names, though convenient as general terms, do not indicate natural divisions. In the more modern and more scientific classification now generally in use among Malacologists the characters of the "radula" or lingual ribbon are those mainly relied upon as distinguishing the primary groups of Prosobranchiates. The form of the "radula" is, however, necessarily unknown in the case of fossil forms, and it is therefore only by means of analogies—which may or may not be trustworthy—that the extinct groups of Prosobranchiates can be ranged in a series

the groups of which are based upon the structure of this organ. All that will be attempted here, therefore, is to give a brief outline of the characters and geological range of the principal families of Prosobranchiates, without regard to the arrangement of these in larger groups. In this outline the "holostomatous" families, as the most ancient and the least highly organised, naturally take precedence of the forms with a "siphonostomatous" shell.

Family 1. Patellidæ.—In this family the animal usually possesses a series of branchiæ arranged marginally in a more or less complete cycle round the foot. The shell is conical, with the apex turned more or less clearly towards the front; and the muscular impression is horse-shoe-shaped and open in front, continuous or broken up into separate cavities. The genus *Acmæa*, often regarded as the type of a special family, differs from *Patella* proper in the fact that there is always a cervical branchial plume, the marginal gills being sometimes present, sometimes absent. As these types, however, cannot be distinguished from one another by their shells alone, this distinction is palæontologically inapplicable.

The typical species of *Patella*, such as the common Limpet (*P. vulgata*), have usually a radially-ribbed shell, with the apex subcentral and turned forwards. Such types are clearly recognisable in the Cretaceous and Tertiary rocks. In *Helcion*, again, the shell is radially-ribbed, and the apex is shifted far forwards. Such types abound in the Jurassic and Cretaceous rocks, and still survive. In *Acmæa*, finally, the apex is usually subcentral and the surface is

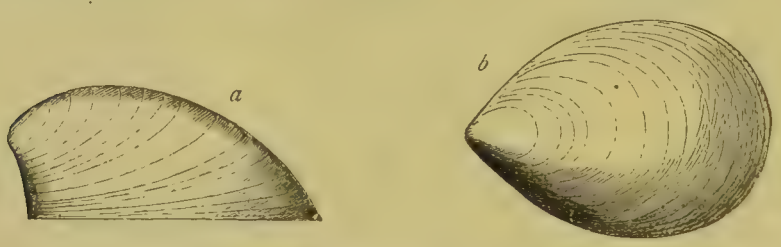


Fig. 644.—*Tryblidium* (*Metoptoma*) *Nycteis*, from the Ordovician of Canada. *a*, Side view; *b*, View of the upper side. (After Billings.)

generally smooth or feebly striated. This type cannot be clearly separated from the preceding except by an examination of the animal, but many of the fossil Limpets doubtless belong here. A Limpet of this type has been described by Hall from the Upper Cambrian (Potsdam Sandstone) of North America under the generic name of *Palæacmæa*.

Most of the Palæozoic Limpets belong to the genera *Tryblidium* and *Metoptoma*, which agree with one another in the fact that the shell (fig. 644) is in the form of an obtuse or shallow cone, with the apex placed very far forwards, so as to be submarginal. In *Tryblidium*, as shown by

Lindström, the muscular scar is in the form of six pairs of disconnected impressions, arranged in an oblong circle which is open in front. The species of this genus are principally Ordovician and Silurian. *Metoptoma*, as now restricted, differs from the preceding in having the anterior side broadly truncated (fig. 645, F), and in the fact that the muscular scar is in the form of a continuous horse-shoe. The genus appears to range from the Ordovician to the Carboniferous, but as the interior markings of many species are unknown, it is impossible at present to sharply separate this type from *Tryblidium*.

Family 2. Fissurellidæ.—In this family the animal has the gills symmetrically disposed on the two sides of the body. The shell is conical and limpet-shaped, with a notch in the anterior

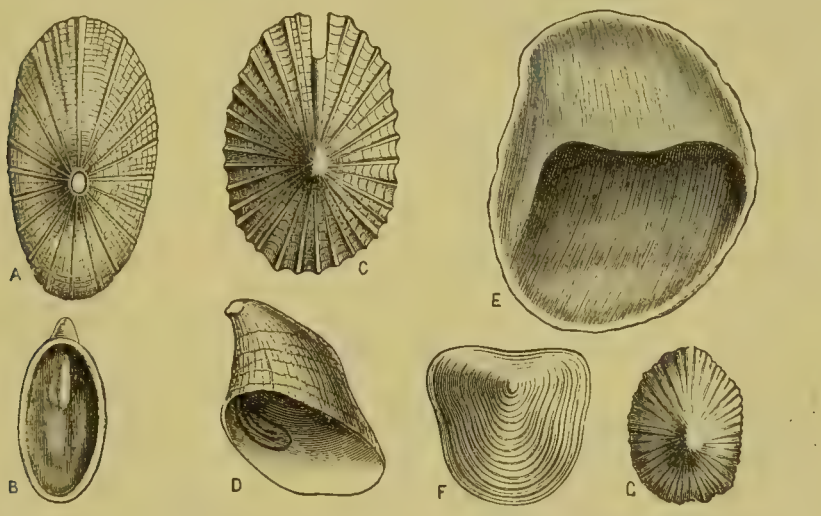


Fig. 645.—Fissurellidæ, Capulidæ, and Patellidæ. A, *Fissurella labiata*—Eocene; B, *Rimula Blainvillei*—Eocene; C, *Emarginula Guerangeri*—Cretaceous; D, *Hipponyx cornucopiæ*—Eocene; E, *Crepidula costata*—Miocene; F, *Metoptoma imbricata*—Carboniferous; G, *Patella costaria*—Eocene.

margin, or a perforation at or near the apex, corresponding with the anus (fig. 645, A and C). The muscular impression is horse-shoe-shaped and is open in front.

The genus *Fissurella* (fig. 645, A) comprises the so-called "Key-hole Limpets," distinguished by having the apex of the shell perforated by a larger or smaller, generally oval aperture. Very dubious examples of the genus have been described from the Devonian and Carboniferous rocks, but the earliest undoubted types appear in the Jurassic rocks, from which time the genus has continued to the present day. In the genus *Rimula* (fig. 645, B), ranging from the Lias to the present day, the perforation, instead of being at the apex of the shell, is placed a little above the anterior margin. Lastly, in *Emarginula* (fig. 645, C) the anterior margin is furnished with a longitudinal notch or slit. The oldest species of this genus has

been found in the Carboniferous Limestone, but most of the fossil forms are Cretaceous and Tertiary.

Family 3. Capulidæ (=*Calyptræidæ*).—In this family the shell is conical and patelliform, with a more or less spiral apex, the interior being simple, or divided by a shelly process to which the adductor muscle is attached. The margin of the shell-aperture is thin and entire, often more or less modified in outline by the habit which the animal possesses of fixing itself, with the aperture closely fitted, to some foreign body, such as a Crinoid.

The genus *Calyptræa*, in the wide sense in which it has generally been defined, includes the so-called "Cup-and-saucer Limpets," in which the interior has a half-cup-shaped process attached to the apex of the shell, and open in front. The earliest forms of this type appear in the Cretaceous rocks, and the genus still survives. In the genus *Crepidula* (fig. 645, E) there is a shelly partition covering the posterior half of the interior of the shell. The fossil forms of this genus date from the Cretaceous period. *Hipponyx*, again, comprises thick and obliquely conical shells, with a posterior apex, and often provided with a shelly basis marked by a distinct horse-shoe-shaped muscular impression (fig. 645, D). The genus ranges from the Cretaceous rocks to the present day.

By far the most important genus of this family, palæontologically speaking, is *Capulus* (*Pileopsis*) itself, including the so-called "Bonnet-limpets" of the present day. The Palæozoic shells which have been included under the name of *Platyceras* (=*Acroculia*) appear to be identical with *Capulus*, or, at any rate, to be distinguished from this by characters of no more than sub-generic value. In the genus *Capulus*, employing this name in the general sense indicated above, the shell is conical, with a posterior sub-spiral apex, and, generally, a horse-shoe-shaped muscular impression. The aperture is greatly enlarged, and its margins are essentially entire; but owing to the fact that the shell is usually affixed for lengthened periods to foreign bodies, the lips may become more or less sinuated or undulated (figs. 646, 647). The shells of this genus may, as a rule, be recognised by their obliquely-spiral or straight, conical shape, their wide aperture, and the absence of a columella. They may be dextral or sinistral, and the surface may be simply marked with concentric lines of growth,



Fig. 646.—*Capulus* (*Platyceras*) *ventricosus*. Silurian. (After Hall.)

or may be ornamented with spines. The genus is abundantly represented in the Silurian and Devonian periods, and less abundantly in the Carboniferous; while ancient types have been described from the Upper Cambrian and Ordovician rocks. Many Secondary and Tertiary species are known, and the comparatively few living species are widely distributed over the globe.



a *b*

Fig. 647.—Different views of *Capulus* (*Platyceras*) *dumosus*, of the natural size. Devonian, Canada. (Original.)

According to Lindström, the name of *Platyceras* may be retained for the Silurian forms of *Capulus*, as presenting certain constant differences, and, in particular, as not having been clearly shown to possess the horse-shoe-shaped muscular scar of the latter. The same authority unites with *Platyceras* the Palæozoic types described under the names of *Platystoma* (Conrad) and *Strophostylus* (Hall). *Orthonychia*, again, includes forms with a nearly straight shell, the spire being very small, and the terminal portion of the shell very large.

Family 4. Velutinidæ.—The principal genus in this family is *Velutina*, in which the shell is thin, with a large body-whorl and small spire, and having a large rounded aperture with an entire margin. The genus is principally Recent and Tertiary, but a few Secondary types have been described.

Family 5. Pleurotomariidæ.—In this family the shell is nacreous, very variable in form, but usually coiled into an elevated or flat spiral. The outer lip of the shell-aperture (fig. 648) exhibits a notch or slit, which in course of growth becomes progressively filled up,

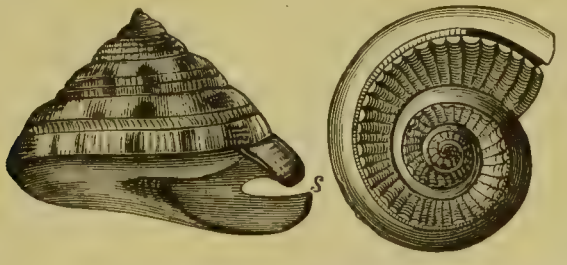


Fig. 648.—Side-view of the recent *Pleurotomaria Quoyana*, showing the slit in the outer lip (*s*); and upper view of *Pleurotomaria platyspira*, showing the slit-band.

thus giving rise to a revolving band upon the whorls; or which may become partially closed and converted into one or more perforations. The animal is provided with a circular horny operculum.

The family *Pleurotomariidæ* has relationships with the *Haliotidæ*, the *Bellerophontidæ*, and the *Euomphalidæ*; and the great majority of the genera included in it are extinct. If *Scissurella* be placed

among the *Trochidæ*, the only genus of the family which still survives is *Pleurotomaria* itself.

The genus *Pleurotomaria* is a "persistent type," the oldest forms appearing in the Upper Cambrian, while four living species have been detected. The genus is very largely represented in the Ordovician, Silurian, Devonian, and Carboniferous rocks. A very limited number of species has been hitherto obtained from the Permian deposits. In the Mesozoic rocks the genus again shows a great development, the Secondary forms being commonly more ornate than those from older rocks. Very few Tertiary species are known, and the few living species are found in the Antilles and in the Japanese seas.

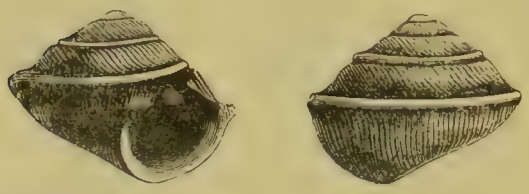


Fig. 649.—*Pleurotomaria Agave.* Ordovician. (Billings.)

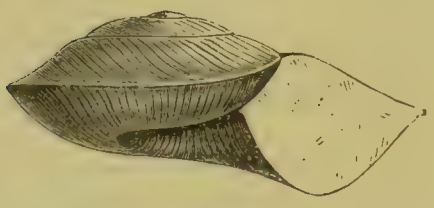


Fig. 650.—*Pleurotomaria Dryope.* Ordovician. (Billings.)

The form of the shell in *Pleurotomaria* (figs. 649, 650) differs considerably in different types, being most generally similar to that of *Trochus* or *Turbo*, but being in other cases very much flattened out and depressed. The shell consists of a few whorls, which are generally in close contact; but the last whorl may be disconnected from the others, or the shell may be entirely evolute (*Odontomaria*). The aperture of the shell is subquadrate, and the outer lip (fig. 648) exhibits a deeper or shallower slit. As the shell grows, this slit becomes progressively filled up, forming a well-marked band on the whorls. By this character *Pleurotomaria* may generally be distinguished readily from such shells as *Trochus* and *Turbo*.

Many subordinate types are included in the comprehensive genus *Pleurotomaria*, in the wide sense. Thus a number of Secondary types admit of separation from *Pleurotomaria* proper by their possession of a very deep slit and a narrow band, and these may be grouped together under the name of *Leptomaria*. In the Carboniferous *Polytremaria* the band on the whorls is partially obliterated, and is perforated by a linear series of minute foramina. In the Jurassic *Ditremaria* there is a kidney-shaped aperture, consisting of two foramina united by a slit, in the band near the outer lip. Lastly, in the Devonian *Odontomaria* the shell is tubular and evolute.

The Silurian genus *Euomphalopterus* is regarded by Lindström as an extreme form of *Pleurotomaria*. In this type the shell is a depressed spiral, the slit-band forming a wide alation, perforated by canals which

open into the cavity of the shell internally, and externally by minute pores on the margin of the wing. Again, in the Triassic and Jurassic genus *Trochotoma* (fig. 651, B) the shell is trochoid, with a concave base, and there is a single elongated perforation in the slit-band, near the margin of the outer lip. The ancient Ordovician types *Scalites*, *Rhaphistoma*, and *Helicotoma*, of which the two last are probably identical,

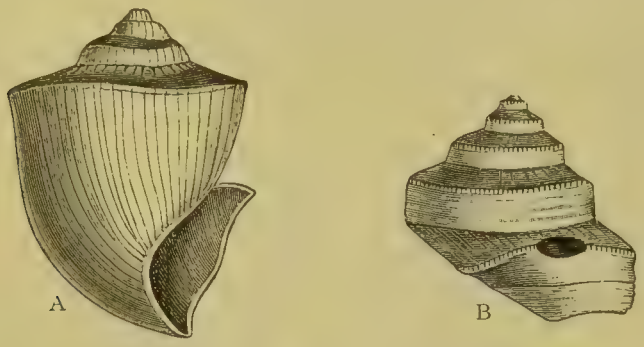


Fig. 651.—A, *Scalites angulatus*, Ordovician, North America. (After Hall.)
B, *Trochotoma affinis*, Jurassic.

appear to be really referable to *Pleurotomaria*. In *Scalites* (fig. 651, A) the shell is spiral, with a flattened spire, the body-whorl ventricose, the "suture" canaliculated, the lip truncated, and the columella imperforate and curved. In *Rhaphistoma* the spire is still more depressed, the "suture" is close, instead of being grooved, there is an umbilicus of moderate size, and the aperture is somewhat trigonal and slightly notched.

The genus *Porcellia* (fig. 652), sometimes regarded as belonging to the *Bellerophontidæ*, seems to be really referable to the *Pleurotomariidæ*. In this genus the shell is discoidal and many-whorled, the outer lip having a deep slit, and the whorls having a well-marked revolving band running along the centre of the dorsal side. The species of *Porcellia* appear to range from the Devonian to the Trias.

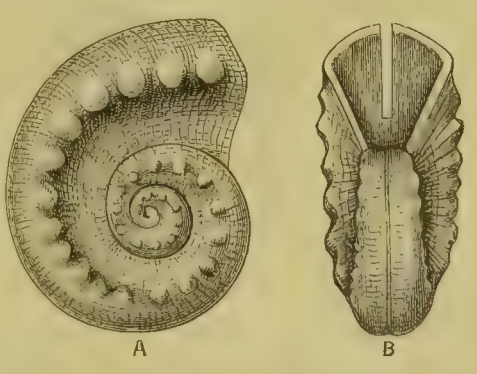


Fig. 652.—*Porcellia puzo*, viewed sideways (A) and from the front (B). Carboniferous.

Lastly, the important genus *Murchisonia* (fig. 653) is nearly related to *Pleurotomaria*, the line of separation between the two groups being, in fact, one which cannot be sharply defined. The shell in the typical forms of *Murchisonia* is long and turreted, the number of the whorls being greater

than in *Pleurotomaria*. The outer lip is deeply notched, and the outer side of the whorls shows the characteristic slit-band of the family. The aperture of the shell is slightly channelled in front, and the surface is often variously sculptured and adorned. The genus ranges from the Ordovician to the Permian rocks, and possibly is represented in the Alpine Trias.



Fig. 653. — *Murchisonia gracilis*. (Hall.) Ordovician.

Family 6. Bellerophontidæ.—In this family the shell (figs. 654, 655) is "nautiloid, generally symmetrical, spirally inrolled; the spire is concealed by the succeeding whorls; the aperture is of large size; the outer lip is arched, sharp-edged, simple, or greatly expanded, carrying in the middle line a sinus or notch, continued on the convexity of the last whorl by a slit-band or by a series of perforations" (Fischer). This family includes the extinct genus *Bellerophon* and its allies, and has been often referred to the order of the *Heteropoda*. The shell in *Bellerophon* is, however, of considerable thickness, and the genus is commonly found associated with forms which undoubtedly inhabited water of comparatively small depth. For these reasons, amongst others, the *Bellerophontidæ* can hardly be associated with a purely oceanic group such as the Heteropods. On the other hand, the presence of a dorsal revolving band on the whorls, and of a sinus or notch in the outer lip, brings the shell in relation with that of the

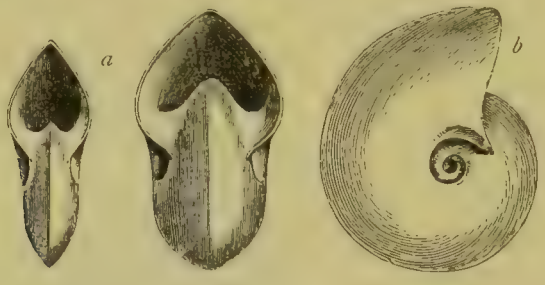


Fig. 654.—*Bellerophon Argo* (Billings). *a*, Front view; *b*, Side view. Ordovician.

Pleurotomariidæ; while an affinity with the *Haliotidæ* is established by the presence in some forms (*Tremanotus*) of a row of apertures on the dorsal keel of the shell. All the members of the *Bellerophontidæ* are extinct, and if the problematical Cretaceous genus *Bellerophina* be excluded, they are exclusively confined to the Palæozoic rocks.

In the genus *Bellerophon* (figs. 654, 655) the shell is symmetrically convoluted, the coils of the shell lying in one plane. The

whorls are few, smooth or sculptured, and there is a dorsal band or keel along the convex margin of the shell. The aperture is often more or less expanded, and is in most instances emarginate or deeply notched on the dorsal side, the columellar lip being generally more or less callous. The genus ranges from the Upper Cambrian to the Permian, but attains its maximum in the Carboniferous Limestone. *Bucania* (Silurian to Carboniferous) includes forms not generically separable from *Bellerophon*, but distinguished by the fact that all the volutions are visible and increase gradually in size

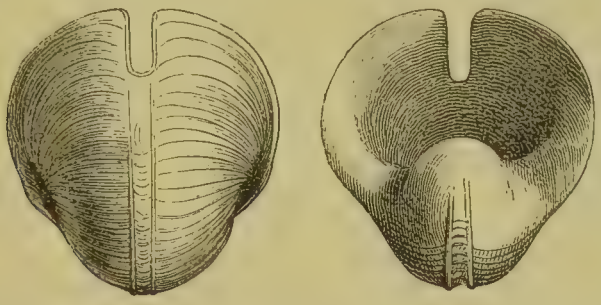


Fig. 655.—*Bellerophon bicarenus*, from the Carboniferous rocks of Belgium. (After Zittel.)

to the expanded mouth. The genus *Tremanotus* (Silurian) resembles *Bucania* in the form of the shell; but the dorsal band is replaced by a series of perforations which become successively filled up in process of growth, and which appear to correspond with the siphonal apertures in the shell of *Haliotis*. Closely allied to *Tremanotus* is the Silurian and Devonian genus *Salpingostoma*, in which there is a single elongated aperture on the dorsal margin of the body-whorl at some distance behind the margin of the lip.

In the neighbourhood of *Bellerophon* must also be placed the genus *Cyrtolites*, in which the shell is symmetrical, discoidal, or coiled into the shape of a horn, the whorls being in contact or more or less disconnected. The aperture is rhomboidal, with a median sinus, and a band or keel is developed on the convexity of the last whorl, while the surface is often sculptured. The genus ranges from the Ordovician to the Carboniferous.



Fig. 656.—*Cyrtolites ornatus*. Ordovician.

The affinities of the genus *Bellerophina*, of the Gault (Cretaceous), are quite uncertain, though it has often been associated with *Bellerophon*. The shell in this genus is globular, spirally inrolled, and nautiloid, but the outer lip has no sinus or notch, and the convexity of the whorls is not furnished with a keel or band. It is not improbable that this genus is really referable to the *Heteropoda*, but the structure of the shell is at present imperfectly known.

Family 7. Haliotidæ.—In this family the shell (fig. 657) is spiral and ear-shaped, nacreous internally, and with a large aperture. The body-whorl exhibits on the left side a series of rounded perforations, which become successively filled up, the last few, however, remaining always open. The last of these apertures corresponds with the anus and transmits a fold of the mantle, while the others give passage to tentaculiform prolongations of the pallial border. This family contains only the genus *Haliotis*, comprising the recent "Ear-shells." The oldest example of this genus is the *H. antiqua* of the Maestricht Chalk, and a few Tertiary species are known.



Fig. 657.—*Haliotis tuberculata*, from the Pliocene Tertiary.

Family 8. Stomatiidæ.—In this family the shell is spiral or ear-shaped, with a short spire, and an expanded entire aperture. The interior is nacreous, and the shell is destitute of the perforations which characterise *Haliotis*. The principal genus in this family is *Stomatia*, the earliest undoubted representatives of which appear in the Jurassic rocks, while others are Cretaceous and Tertiary, and a few forms still survive.

Family 9. Euomphalidæ.—As defined by De Koninck, the genera comprised in this family possess a spiral shell, sometimes elevated, sometimes discoid, the whorls being in contact or disjunct, and a larger or smaller umbilicus being present. The outer lip of the aperture exhibits one or two (rarely three) larger or smaller sinuses, of which the surface often shows only slight traces, except that their existence is usually marked by keels or by imbricated lamellæ of growth. The inner portion of the shell is often partitioned off by successively produced transverse septa; and a shelly operculum is sometimes present. Professor De Koninck includes in this family a number of extinct, mostly Palæozoic, genera, which are probably in some cases referable to different groups, but which will be here considered together, as a matter of convenience. On the other hand, none of the genera placed here by De Koninck are admitted into this family by Lindström except *Euomphalus* proper, while by this authority *Loxonema* is associated with *Euomphalus*.

The two principal types included in the *Euomphalidæ*, as defined by De Koninck, are *Straparollus* and *Euomphalus*, which many authorities have regarded as so nearly related as to have merely the standing of sub-genera, while Lindström considers them as belonging to entirely different families. In *Straparollus* (fig. 658) the shell is thick, typically conical, with a more or less prominent spire

and a large umbilicus, the whorls being rounded and non-angulated, the mouth round or oval, and the surface smooth or striated. The species of this genus range from the Silurian to the Trias. Apparently related to the preceding is *Platyschisma*, in which the shell is thin, obtusely conical, ventricose, umbilicated, and smooth, "with a shallow sinus in the outer lip, but with no defined band" (R. Etheridge, jun.) The genus appears to range from the Silurian to the Carboniferous.



Fig. 658.—*Straparollus Dionysii*, from the Carboniferous Limestone of Belgium. (After Zittel.)

The genus *Euomphalus* (fig. 659), as defined by Lindström, comprises discoidal shells, in which the whorls are contiguous or disjunct; the umbilicus is wide; and the outer lip of the aperture possesses on its upper side a shallow notch or sinus, which gives rise to a more or less elevated revolving ridge or keel in the middle or upper part of the convexity of the whorls. The mouth of the shell is more or less angulated, while the apex is filled up with a secondary deposit of shell, and the interior is often divided off by transverse shelly partitions. The species of *Euomphalus* range from the Silurian to the Carboniferous, one of the most familiar types being the *E. pentangulatus* (fig. 659) of the Carboniferous Limestone. The well-known Silurian shells which have been described under the names of *Euomphalus discors* and *E. rugosus* have been shown by Lindström to have possessed a nacreous shell, and to be referable to the *Turbinidæ*.

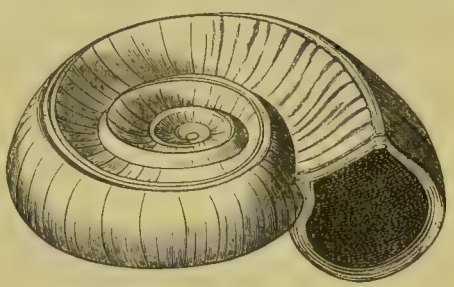


Fig. 659.—*Euomphalus pentangulatus*, of the natural size, from the Carboniferous Limestone of Ireland. (After Woodward.)

The name of *Schizostoma* is applied by De Koninck to forms with a shell (fig. 660) essentially similar to that of *Euomphalus*, as above described, but having two spiral keels, one on the upper and one on the lower aspect of the convexity of the whorls. It would seem that *Ophileta* is a synonym of *Schizostoma*, and in that case forms of this type range from the Ordovician to the Carboniferous. The forms to which the name of *Ecculiomphalus* has been applied (fig. 661) would appear, again, to be essentially identical with *Euomphalus*, from which they differ simply in the fact that the shell is evolute, the whorls not being in contact. Forms of this type are known to range from the Ordovician to the Carboniferous.

The name of *Cœlocentrus* (= *Cirrus*, De Koninck) is given by Zittel to certain Palæozoic types which have a general resemblance to *Euomphalus*, the shell being a flat spiral, with a large umbilicus (fig. 662). The shell differs from that of *Euomphalus* proper in the fact that the mouth is round, the outer lip is not sinuated, the



Fig. 660.—*Schizostoma* (*Ophileta*) *bella* (Billings). Different views of a nearly perfect specimen. Quebec Group (Ordovician).

whorls are more or less rounded, and the volutions support one or two rows of prominent spines.

Discohelix includes discoidal shells, concave on both faces, with the whorls flattened at the circumference, and furnished with two marginal keels, the aperture being quadrangular. Forms of this type appear to be principally characteristic of the Upper Trias and

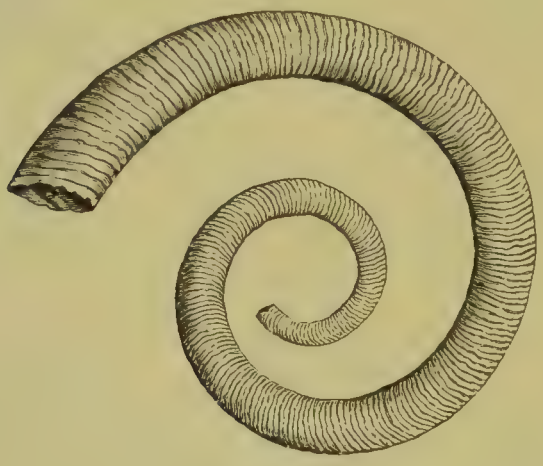


Fig. 661.—*Ecculiomphalus distans*. Quebec Group (Ordovician).

of the Jurassic rocks. *Bifrontia* (Eocene) appears to be nearly related to *Discohelix*.

The remarkable Palæozoic genus *Maclurea* (fig. 663) may be provisionally placed here; though its precise affinities are very doubtful, and it is regarded by Fischer as probably related to the

Neritidæ. In this genus the shell is discoidal, of few whorls, longitudinally grooved at the back, and ornamented with lines of growth.

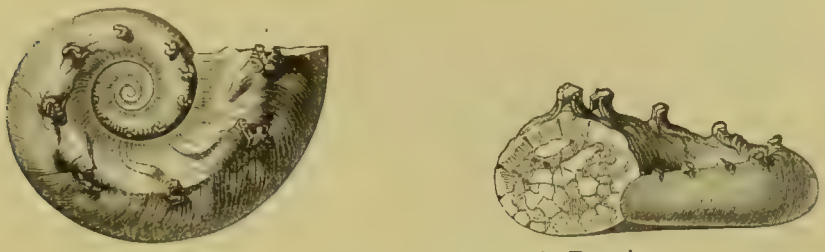


Fig. 662.—*Cœlocentrus* (*Cirrus*) *Goldfussi.* Devonian.

The upper side of the shell (drawn as the lower side in fig. 663, *b*) is convex, and deeply umbilicated by the sinking of the spire below

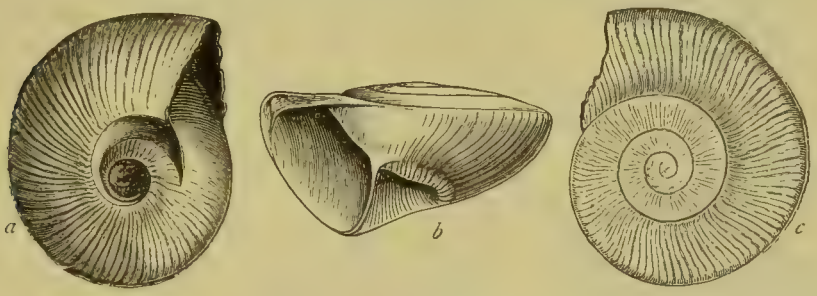


Fig. 663.—*Maclurea crenulata,* Ordovician (Quebec Group), Canada. *a,* Upper side, with the spire; *b,* Side view of the shell; *c,* Base. Properly speaking, figure *b* should have been drawn with the flattened base undermost and the hollow spire above. (After Billings.)

the general surface; while the base is flattened and exposes the inner whorls. The mouth of the shell is closed by a shelly operculum,



Fig. 664.—*Pleuronotus* (*Euomphalus*) *De-Cewi* (Billings). *a,* Front view; *b,* View of the umbilicus. Devonian, North America.

which is "sinistrally sub-spiral, solid, with two internal projections, one of them beneath the nucleus, very thick and rugose" (Woodward). The genus is essentially characteristic of the summit of the

Cambrian and the base of the Ordovician series (the Quebec Group and Chazy Limestone in North America, the Durness Limestone in Scotland, &c.)

Finally, we may notice here the Devonian fossil for which Billings proposed the name of *Euomphalus De-Cewi*, and upon which Hall has based the genus *Pleuronotus*. In this form (fig. 664) the shell is discoidal, with a wide shallow umbilicus and a concave spire, the outer lip of the aperture showing a distinct sinus. The surface on the summit and external side of the whorls is "marked by a distinct band, to the margins of which the surface-striæ converge on the two sides, and upon which they make a regular retral curve" (Hall). This last character renders it probable, as suggested by Hall, that *Pleuronotus* should be referred to the family of the *Pleurotomariidæ*.

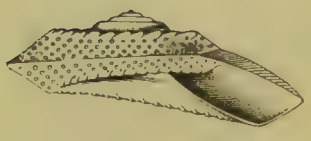


Fig. 665.—*Solarium ornatum*. Gault (Upper Cretaceous).

Family 10. Solariidæ. — In this family the shell is obtusely conical or depressed, with a large and deep umbilicus running from the base to the apex of the shell. There is no nacreous layer, and the aperture is entire. The principal genus in this family is *Solarium* itself (fig. 665), comprising the familiar "Staircase Shells." In this genus the edge of the umbilicus is typically crenulated, and the aperture is rhombic. The species of *Solarium* range from the Cretaceous (Trias?) to the present day.

Family 11. Trochidæ.—In this family the shell is conical, pyramidal, top-shaped, or helicoid, the aperture being entire, and either quadrilateral or round in form. The shell is *nacreous*, and the operculum is horny, circular, and multispiral, with a central nucleus. The members of this family are all marine, and are mostly found between tide-marks or in shallow water; a few forms, however, being inhabitants of deep water.



Fig. 666. — *Trochus conulus*. Pliocene Tertiary.

In the genus *Trochus* (fig. 666) the shell is pyramidal, with a nearly flat base, and the aperture is oblique and rounded in shape. The range of the genus is from the Silurian to the present day, but the determination of many of the fossil forms is uncertain, since it is by the structure of the operculum that the genus is essentially distinguished from *Turbo* and *Astralium*, and

opercula, even when shelly and massive, are not often met with in the fossil condition.

Monodonta in its general characters resembles *Trochus*, but the columella is thickened and carries a prominent tooth. The genus ranges from the Tertiary period to the present day, and doubtful representatives of it have been indicated as occurring in older times. In *Delphinula* the shell is orbicular and depressed, the whorls angulated or coronated, often spiny, the mouth round, the peristome entire, and the umbilicus open. The genus seems to begin in the Jurassic rocks. In *Umbonium* the shell is circular, with a short spire and a large body-whorl, the surface being polished, and the umbilical region covered with a prominent callosity. The genus begins in the Devonian, and still survives. Lastly, according to the views of Lindström, we must include in this family the genus *Scissurella* (fig. 667), in which the shell is thin, with a greatly expanded body-whorl, and the outer lip is furnished with a deep slit. The earliest forms of *Scissurella* appear in the Cretaceous rocks, and the genus still survives.



Fig. 667.—*Scissurella aspera.* Pliocene Tertiary.

Family 12. Turbinidæ.—The shell in this family is solid and nacreous internally (except in *Phasianella*), turbinated or trochoid in form, with an entire, round or oval aperture, and a rounded or flat base. The operculum is calcareous, paucispiral, with a central or excentric nucleus. The members of this family are marine, and inhabit shallow water.

In the genus *Turbo* (fig. 668) the shell is turbinated, with a round base, the whorls being convex, and the aperture large and rounded. The species of the genus range from the Silurian to the present day, about four hundred fossil species having been described; but owing to the non-preservation of the opercula there is much doubt as to the true position of many of the older forms.



Fig. 668.—*Turbo subcostatus.* Devonian.

In *Astralium* (*Imperator*) the shell is trochoid, with a flat or concave base, and with keeled or foliaceous whorls and an angulated aperture. The genus ranges from the Trias to the present day. The genus *Oriostoma* (fig. 669) comprises Silurian and Devonian forms, in which the shell is discoid, with a short spire, the whorls being in contact, but the last whorl sometimes partially disjunct. The surface is usually spirally ribbed; there is a wide and open umbilicus; and the aperture has thin lips, without a sinus. The inner layer of the shell is nacreous, and there is a solid calcareous operculum. Some of the most familiar of the Silurian forms, such as *O. discors* (fig. 669), *O.*



Fig. 669.—*Oriostoma* (*Euomphalus*) *discors.* Silurian, Britain.

rugosum, and *O. sculptum*, have been described as species of *Euomphalus*.

In *Cyclonema* (fig. 670, B) the shell is turbinated and imperforate, and the surface is adorned with raised spiral lines intersected by finer transverse striæ. The genus ranges from the Ordovician to the Devonian. The Devonian genus *Isonema* resembles *Cyclonema*, but the whorls are angular and the aperture is rhombic. In *Eunema* (fig. 670, A), again, the spire is elevated, the whorls are more or less angular, and the surface is adorned with elevated spiral ribs. The genus begins in the Ordovician, and the typical forms are Palæozoic. The Secondary genus *Amberleya*, however, seems to differ from *Eunema* principally, if not solely, in the fact that the spiral ribs are replaced or accompanied by rows of tubercles or nodosities. The Silurian and Devonian genus *Trochonema* resembles *Cyclonema*, but there is a wide umbilicus, bordered by an elevated ridge. In the Silurian genus *Craspedostoma* the shell is globular, the surface has transverse lamellar ribs, and there is a circular mouth "enclosed within an enormously enlarged and thickened border" (Lindström).

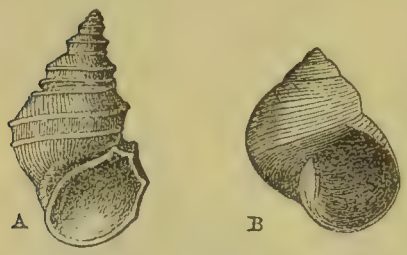


Fig. 670.—A, *Eunema strigillatum*, Ordovician (Trenton Limestone), Canada; B, *Cyclonema bilix*, Ordovician (Cincinnati Group), North America. (After Zittel.)

The genus *Phasianella* (fig. 671) represents another type of the *Turbinidæ*, in which the shell is not nacreous, and its surface is smooth and polished. The spire is long, the body-whorl is large, and the aperture is oval. The genus ranges from the Devonian to the present day.



Fig. 671.—*Phasianella melanoides*. Eocene Tertiary.

Family 13. Xenophoridæ.—This family includes only the genus *Xenophora* (*Phorus*), in which the shell (fig. 672) is trochoid, with a concave or flattened base and keeled whorls, but differs from that of the *Trochidæ* in not being nacreous. Very commonly, foreign bodies, such as shells or small pieces of stone, are attached to the surface and margins of the shell. The genus ranges from the Devonian to the present day.

Family 14. Neritidæ.—In this family the shell is thick and globular, with a very small spire, and without an umbilicus. The aperture is semilunate, its columellar side thickened and expanded, and often toothed (fig. 673), and the outer lip acute. There is a calcareous, sub-spiral operculum, provided with a process on its inner side. The "Nerites" are inhabitants partly of salt water and partly of fresh or brackish waters. In many cases the inner turns of the spire become absorbed in process of growth, so that casts of the interior of the fossil forms often show no traces of a spire.

In the genus *Nerita* (fig. 673) the shell is thick, with a broad columella, the inner edge of which is straight and toothed. The outer lip is thickened and often denticulated internally. The true Nerites are inhabitants of warm seas; and typical forms of the genus

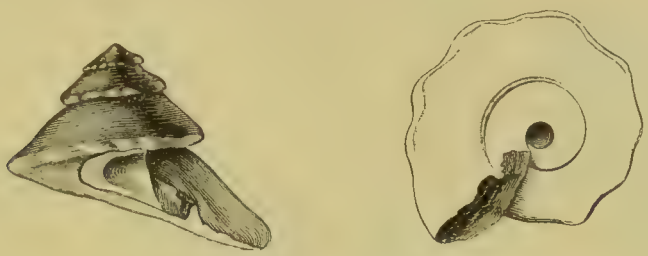


Fig. 672.—*Xenophora* (*Phorus*) *canaliculata*. Cretaceous.

appear first in the Cretaceous rocks, though nearly related types are known from the Triassic and Jurassic rocks.

The Triassic and Jurassic genus *Neritodomus* closely resembles *Nerita*, but the columellar lip of the aperture is thickened and callous, and is without teeth. In the nearly allied *Neritoma*, of the Jurassic rocks, the shell is thick and ventricose, and the columellar lip is callous, and is not toothed, while there is a notch or sinus in the middle of the outer lip.

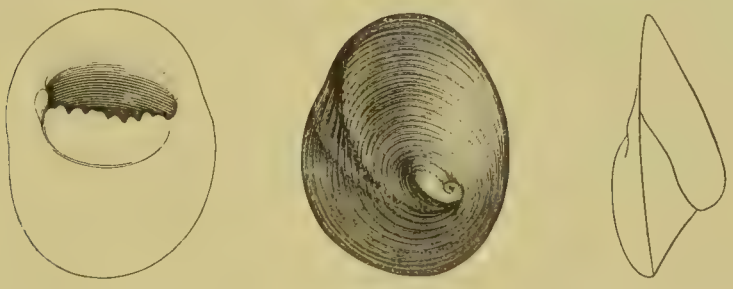


Fig. 673.—*Nerita* (*Velates*) *Schmideliana*. Eocene Tertiary.

The genus *Neritina*, again, includes the so-called "Fresh-water Nerites," which agree in most characters with *Nerita*, but inhabit fresh or brackish waters, and have a comparatively thin smooth shell. The oldest forms of *Neritina* seem to appear in the Lias, and the genus is abundantly represented in the fresh-water deposits of the Tertiary period, while many recent forms exist. Lastly, the genus *Pileolus* comprises small limpet-shaped shells, with a semilunar aperture. The range of the genus is from the Jurassic to the Eocene.

Family 15. Neritopsidæ.—In this family the shell resembles that of *Nerita* or *Natica* in shape, and is thick and imperforate. The aperture is entire, semilunate, or oval in form; and there is a thick shelly operculum, oval in shape, and non-spiral. In *Neritopsis* the shell is shaped like that of *Nerita*, of few volutions, and with a

short spire; and the columellar lip of the aperture is largely excavated about its middle. The genus ranges from the Trias to the present day. The name of *Peltarion* has been given to oval or nearly circular calcareous plates, concave above and flattened below, which are found in the Jurassic rocks, and which are now known to be the opercula of species of *Neritopsis*. Similar opercula occur in the Upper Trias and in the Tertiary rocks. The extinct genus *Naticopsis* (fig. 674) includes thick, imperforate, naticoid shells, with

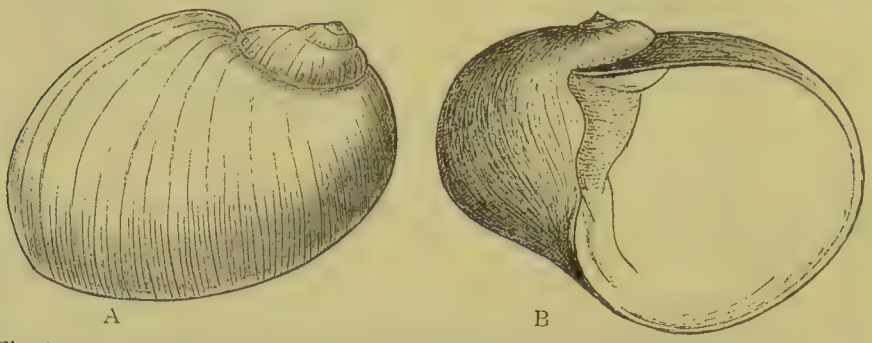


Fig 674.—A, *Naticopsis plicistria*, Carboniferous Limestone. (After M'Coy.) B, *Naticopsis ampliata*, Carboniferous Limestone. (After De Koninck.)

a short spire and a large body-whorl. The aperture is oval, and the columellar lip is callous and flattened, the outer lip being thin. A calcareous operculum is present. The genus ranges from the Devonian to the Upper Trias.

Family 16. Helicinidæ.—This family includes the recent *Helicina* and its allies, in which the shell is helicoid and globular, with a short spire, the interior turns of the spire being absorbed in course of growth. The aperture is semicircular, and a horny or calcareous operculum is present. This family has been generally included among the *Pulmogastropoda*, upon the ground that the breathing-organ is in the form of a pulmonary chamber, and the animal is terrestrial; but the true relationships of the group appear to be with the *Neritidæ*. All the undoubted forms of this family are Recent; but Fischer is inclined to place here the Carboniferous genus *Dawsonella*, which has been commonly included among the *Helicidæ*. In this genus the shell is like that of *Helix* in shape, with a small aperture, the outer lip of which is thickened, while the columellar lip is expanded into a large callosity, which covers the whole umbilical region.

Family 17. Naticidæ.—In this family the shell is globular, of few whorls, with a small spire (fig. 675); the aperture oval, rounded in front, and narrow behind, with an acute outer lip, and commonly with a callous inner lip. The foot is very large, and the mantle-lobes hide more or less of the shell. The operculum is pauci-

spiral, with an excentric nucleus, and may be either horny or calcareous.

The shell in *Natica* (fig. 675) is globular, with a large body-whorl, usually smooth and polished, and often with coloured markings. The inner lip is callous, and the shell is umbilicated, though the umbilicus may be partially or wholly filled up. A large number of recent, and a still larger number of fossil, forms of *Natica* are known, species having been described from rocks as old as the Silurian. It is, however, very questionable if any true forms of *Natica* are known from any Palæozoic deposit, anterior to the Carboniferous at any rate. The most typical forms of *Natica*, in a strict sense, possess a wide umbilicus and a twisted columella, and the oldest shells of this type are from the Eocene Tertiary.



Fig. 675.—*Natica clausa.* Post-Pliocene.

Ampullina includes Eocene and Miocene forms, in which the columella is only slightly thickened and is not twisted. *Amauropsis* includes a number of fossil forms, of which the earliest perhaps appear in the Carboniferous Limestone, while many others are found in the Secondary rocks and the Eocene. In these types there is no umbilicus or only a narrow umbilical fissure, and the spire is moderately high. *Lunatia*, again, includes a series of forms, ranging from the Trias to the present day, in which the aperture is semilunar, and the umbilicus is of moderate or small size, and is without a spirally-twisted callus. The Eocene and Oligocene genus *Deshayesia* has the inner lip covered with a thick callosity, which largely conceals the umbilicus and is toothed on its apertural edge. The Jurassic and Cretaceous genus *Tylostoma*, lastly, includes forms with an elevated spire, and without an umbilicus, the outer lip being thin and sharp.

The genus *Narica* (*Vanikoro*) includes forms in which the shell has a general likeness to that of *Natica* (fig. 676), but the surface is spirally striated, or cancellated. The aperture is semilunate or oval, and the columella is excavated or umbilicated. The genus ranges from the Jurassic period to the present day. *Naticella* (Silurian to Trias) resembles *Narica*, but has no umbilicus or a small one. Lastly, in *Sigaretus* (fig. 677) the shell is ear-shaped, with a spirally-striated surface, a minute spire, and a very large

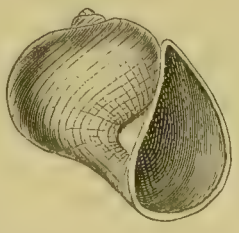


Fig. 676.—*Narica* (*Vanikoro*) *Genevensis*, from the Cretaceous rocks.



Fig. 677.—*Sigaretus clathratus*, from the Eocene.

body-whorl and wide aperture. The species of this genus are Tertiary and Recent.

Family 18. Paludinidæ.—In this family the shell is conical or globular, with a thick epidermis, and with convex whorls, the aperture being entire and sometimes furnished with a continuous lip The operculum may be horny or shelly. The members of this family are essentially fresh-water forms, though some are found in brackish waters, and *Ampullaria* is known in some cases to inhabit salt water. As a matter of course, therefore, they are chiefly, if not exclusively, found as fossils in deposits which are believed to be fluviatile, lacustrine, or estuarine in origin.

The genus *Vivipara* (*Paludina*) comprises forms with a conical shell, a generally smooth surface, and a horny operculum, an umbilicus being sometimes present, sometimes absent (fig. 678, A). The oldest forms of *Vivipara*, in the wide sense, are found in the Lower Cretaceous rocks (Wealden Beds), and a large number of Tertiary and Recent species are known. *Bithynia* resembles *Vivipara*, but the operculum is partially calcified; and its range in time is the same, though the known fossil forms are few in number. In *Valvata* (fig. 678, B) the shell may be top-shaped or discoidal; an umbilicus is present, and the peristome is entire. The earliest undoubted forms of this genus appear in the Upper Jurassic rocks (Purbeck Beds), and a small number of Tertiary and Recent forms are known. Lastly, in *Ampullaria* (fig. 639) the shell is globular, with a short spire and a ventricose body-whorl, and with or without an umbilicus. The operculum may be horny or calcareous. The geological range of *Ampullaria* is a matter of uncertainty, from the difficulty, or impossibility, of separating the shells of this genus from those of *Natica* and its allies. Forms from rocks as old as the Lias have been referred to *Ampullaria*, but it is doubtful if any representatives of the genus are known to occur in the fossil condition.

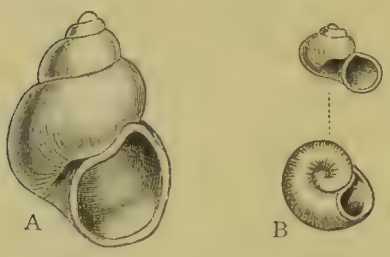


Fig. 678.—A, *Paludina lenta*, Pliocene; B, *Valvata piscinalis*, viewed from in front and from below. (After Searles Wood.)

Family 19. Rissoidæ.—In this family the shell is spiral, usually with an elevated spire, the aperture being entire and rounded, and the operculum horny and spiral. The members of this family are partly marine, partly inhabitants of brackish waters or marshes; and the two principal genera comprised in it are *Rissoa* and *Hydrobia*.

In the genus *Rissoa* (fig. 679) are included small, thick shells, generally more or less ribbed or striated, pointed in shape, many-whorled, and with a small round aperture surrounded by a continu-

ous peristome. The species of *Rissoa* are inhabitants of the sea, and the range of the genus in time is from the Jurassic to the present day. Forms of sub-generic value, or allied types, are *Rissoina* (Jurassic to Recent), *Keilostoma* (Chalk to Oligocene), *Diastoma* (Eocene), and *Pterostoma* (Eocene).



Fig. 679.—*Rissoa supracostata*, enlarged six times. Pliocene. (After Searles Wood.)

Hydrobia is nearly related to *Rissoa*, but the shell is usually thin and smooth. The species of this genus are mostly inhabitants of brackish or fresh waters, but a few live in the sea. The earliest forms of *Hydrobia* are recorded from the Jurassic rocks, but the genus is mainly Tertiary and Recent. The genus *Assiminea* differs from *Hydrobia* almost wholly as regards the animal, but forms are stated to occur in rocks as old as the Eocene.

Family 20. Littorinidæ. — In this family the shell is spiral, top-shaped, not nacreous internally, with a rounded and entire aperture and a simple thin outer lip. The operculum is horny and paucispiral. The members of this family are wholly marine; and their shells are very similar to those of the *Trochidæ* and *Turbinidæ*, except that there is no nacreous layer developed.

In the genus *Littorina* are the true Periwinkles, distinguished by their thick, generally top-shaped and pointed shells, of few whorls, and with an imperforate columella. The undoubted fossil species range from the Jurassic to the present day. In the Tertiary and Recent genus *Lacuna*, the shell resembles *Littorina* in most respects, but it is thin, and the columella is flattened and is bordered by an umbilical fissure. We may also include here the Silurian and Devonian genus *Holopea* (fig. 680), in which the shell is spiral, and either conical, or, more usually, naticoid, with a short spire and a large body-whorl. The surface is smooth or marked with faint transverse striæ; the outer lip is thin; the aperture is entire; and there may or may not be a narrow umbilicus.



Fig. 680. — *Holopea Guelphensis*. (Billings.) Silurian.

Family 21. Scalariidæ.—In this family the shell is spiral and turreted, many-whorled, the volutions marked with longitudinal ribs; and the aperture is round and furnished with a continuous peristome. The shell is perforated, but the umbilicus is often closed or concealed; and the operculum is horny and spiral.

In *Scalaria* itself are included the "Wentle-traps," in which the shell is elongated and many-whorled (fig. 681), and the volutions are adorned with transverse ribs, while the peristome is continuous round the circular aperture. The earliest forms of this genus

appear in the Trias, and a number of Jurassic and Cretaceous species are known; while the genus is largely represented in the Tertiary rocks and at the present day. In the Jurassic genus *Exelissa*, the essential characters agree with those of *Scalaria*, but the shell is of small size, the aperture is constricted, and the last whorl may be partially disjunct. The Triassic genus *Cochlearia* differs from *Scalaria* in having the whorls keeled and spirally striated, the transverse ribs being feebly or not at all developed, while the mouth is thickened and trumpet-shaped; and the Devonian genus *Scoliostoma* resembles *Cochlearia* except that the last volution is bent upwards and the surface is cancellated. Lastly, we may place here the ancient genera *Callonema* and *Holopella*, which agree with the typical members of this family in having a conical shell with an aperture surrounded by a continuous peristome. *Callonema* ranges from the Ordovician to the Devonian, and has the surface ornamented by remote, transverse, lamellar ribs; while in *Holopella* the ribs are reduced to mere striæ, or are obsolete.



Fig. 681.—*Scalaria Grænlandica*. Post-Pliocene and Recent.

Family 22. Ianthinidæ.—The type of this family is the singular pelagic genus *Ianthina*, in which the shell is thin and turbinated, with an oval or subquadrate aperture, the outer lip being thin, and the columella slightly twisted. On the ground of similarity as regards the characters of the radula, *Ianthina* is placed by Fischer in the vicinity of the *Scalariidæ*. The only known fossil forms are from the Pliocene deposits of Italy.

Family 23. Turritellidæ.—In this family the shell is spiral, many-whorled, turreted, the surface spirally ribbed or striated. The aperture is round or subquadrate, entire, but sometimes slightly notched in front. The outer lip is thin, and the operculum is horny. All the members of this family are marine, and, if *Vermetus* and *Cæcum* be excluded, the principal representative of the group is *Turritella* itself (fig. 682), the characters of which are therefore those given above. Many living *Turritellæ* are known, and a still larger number of fossil forms have been described, the earliest unquestionable representatives of the genus occurring in the Jurassic, or perhaps in the Triassic deposits. Most of the fossil species, however, are found in the Tertiary rocks.

Family 24. Vermetidæ.—In this family the shell (fig. 683) is tubular, more or less spiral at first, but with its last turns disjunct. The aperture is round, and is entire or furnished with a lateral slit. A horny circular operculum is usually present. All the members of

this family are marine, and the two principal types are *Vermetus* and *Siliquaria*. The genus *Vermetus* is remarkable for the resemblance of its tubular shell to the calcareous tubes of *Serpula*. The shell is usually attached to some foreign body, and though regularly spiral when young, is always irregular in its growth when adult. The fossil species are best distinguished from *Serpula* by the fact that the tube is repeatedly partitioned off by calcareous septa as the animal grows. It is, however, often a matter of extreme difficulty to determine whether a given specimen be a *Vermetus* or a *Serpula*. The range of *Vermetus* in time, using this name in its wide sense, is from the Carboniferous period to the present day; but most of the fossil forms belong to the later Secondary and Tertiary deposits. In the

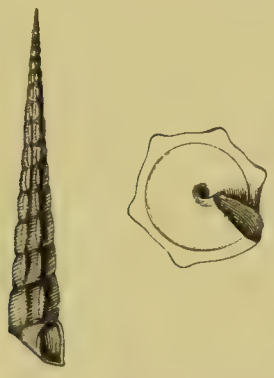


Fig. 682.—*Turritella angulata*.
Neocomian.



Fig. 683.—*Siliquaria anguina*.
Pliocene and Recent.

genus *Siliquaria* (fig. 683) the shell resembles that of *Vermetus* in most respects, but it is free, and the tube has a continuous longitudinal slit, which may be replaced by a row of pores, running along the whole length of the shell on one side. The genus ranges from the Cretaceous to the present day.

Family 25. Cæcidæ.—This family comprises only the genus *Cæcum*, in which the shell is free, and, to begin with, forms a small flat spiral. With age, however, the shell becomes decollated, and has in its adult state the form of a curved cylindrical tube, the truncated end of which is closed by a transverse calcareous partition. A number of recent and a few fossil forms of the genus are known, the oldest of the latter being found in the Eocene Tertiary.

Family 26. Pyramidellidæ.—In this family the shell is spiral and turreted, often with a polished surface. The aperture is small and entire, sometimes with one or more prominent plaits on the columella. The operculum is horny, ear-shaped, and paucispiral. All the members of this family are marine, and most of the living forms are of small size.

In *Pyramidella* (fig. 684, B) the shell is slender and turreted, and the columellar lip is plaited. The genus is represented by a number of Recent and Tertiary species, while still older forms occur in the Cretaceous rocks. *Odostomia*, with a similar geological range, includes minute turreted shells very similar in most respects to *Pyramidella*, but having a single tooth-like columellar fold. *Turbonilla*, with the same range in time, nearly resembles the preceding, but the columellar lip is simple, or has a feeble oblique fold. *Chemnitzia* (fig. 684, C) includes a number of slender, turreted, many-whorled shells, with plaited whorls and a simple aperture, the columellar lip having neither teeth nor folds. Numerous fossil forms are known in the Triassic, Jurassic, and Cretaceous deposits, in marine sediments only; and there are also Tertiary species. It is doubtful if the distinction between *Chemnitzia* and *Turbonilla* can be maintained. *Eulima* (fig. 684, A) includes small, polished, elongated shells, with level whorls and a reflected inner lip. The genus ranges from the Trias to the present day, a large number of species occurring in the Tertiary deposits. *Niso*, with the same geological range, has the shell umbilicated, but otherwise resembles *Eulima*.



Fig. 684.—A, *Eulima vagans*, Jurassic (after Morris and Lycett); B, *Pyramidella læviuscula*, Pliocene (after Searles Wood); C, *Chemnitzia internodula*, Eocene (after Searles Wood).



Fig. 685.—*Loxonema rugifera*, Carboniferous Limestone. (After Phillips.)

Family 27. Pseudomelaniidæ.—This family has been founded for the reception of certain extinct marine Gastropods, of which *Loxonema* and *Macrocheilus* are the two most important types. In this family the shell is many-whorled and turreted, with an oval aperture, which is typically entire, but is occasionally notched in front. The columella is simple, or may be slightly folded anteriorly. The forms included in this family have a general resemblance to *Melania*, but they are found in deposits of marine origin, whereas the *Melaniæ* are inhabitants of fresh water.

The shell in *Loxonema* (fig. 685) is long and turreted, with convex whorls, which have no spiral band; and the surface is covered with longitudinal, often more or less arched striæ or ribs, while the outer lip is more or less sinuated. The genus ranges from the

Silurian to the Trias, but attains its maximum development in the Carboniferous Limestone.

The genus *Macrocheilus* (fig. 686) includes thick smooth shells, with a moderately long spire and a pointed apex, and with convex whorls. The aperture is oval, not distinctly notched; the inner lip is callous, and the columella is imperforate and obtusely folded in front. The genus ranges from the Devonian to the Trias, the majority of the known species being Carboniferous. No species of the genus has been detected in the later Secondary or Tertiary deposits, but a living Japanese shell has been referred here. The Devonian and Carboniferous genus *Orthonema* appears to be related to *Loxonema*, and the Carboniferous genus *Soleniscus* has been placed here, though the aperture is canaliculated in front. Lastly, the Secondary and Tertiary genus *Pseudomelania* finds a place in this family.



Fig. 686.—*Macrocheilus arculatus*. Middle Devonian.

Family 28. Melaniidæ. — In this family the shell is spiral and turreted, covered with a thick epidermis, and often much eroded towards the apex of the spire. The aperture is oval, and either entire or channelled or notched in front (fig. 687), the outer lip being acute. The operculum is horny and spiral. The members of this family are essentially fresh-water Gastropods, a few forms only inhabiting brackish waters.

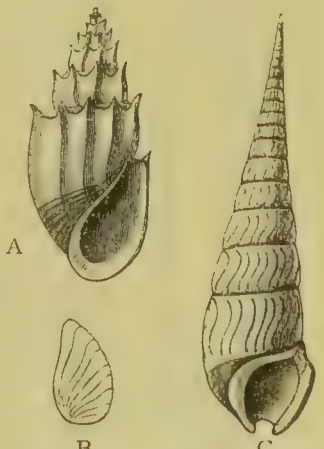


Fig. 687.—A, *Melania amarula*, and (B) its operculum, Recent; C, *Pirena atra*, Recent. (After Woodward)

In *Melania* itself the shell is usually adorned with striæ, ribs, or spines, and the aperture is entire and pointed above (fig. 687, A). The recent species of *Melania* have an exceedingly wide geographical range, and fossil forms are found in moderate numbers in the Cretaceous and Tertiary deposits. In *Pleurocera* the aperture is canaliculated below, and the outer lip is sinuated. The recent forms of this type are North American, and the genus has numerous representatives in the Cretaceous and Tertiary deposits. In *Melanopsis*, lastly, the aperture is deeply notched, and the spire is often shortened; while in *Pirena* (fig. 687, C) the aperture has the same form, but the shell

is turreted. Both genera range from the Cretaceous period to the present day.

Family 29. Cyclostomidæ.—In this family are included terrestrial Gastropods, which possess a pulmonary chamber, and which have therefore been commonly included among the *Pulmogastropoda*. The shell is of variable shape, spiral, sometimes conical (fig. 688), sometimes depressed or discoidal. The aperture is nearly circular, and the peristome is simple or reflected. An operculum is present, and is usually more or less extensively calcified. The principal genus in this family is *Cyclostoma* (fig. 688) itself, which has been split up into a number of subordinate groups. The oldest forms of *Cyclostoma*, in the general sense, appear in the Cretaceous rocks, and a number of Tertiary species are known, while the genus is largely represented at the present day.



Fig. 688.—*Cyclostoma Arnoudii*. Eocene Tertiary.

Family 30. Aciculidæ.—This family includes small terrestrial Gastropods, provided, like the preceding, with a pulmonary chamber. The shell is elongated and cylindrical, with a blunt apex, and a thickened peristome. There is an operculum, but this is never calcified. The recent genus *Acicula* is represented in the later Tertiary deposits.

The genus *Truncatella*—sometimes regarded as the type of a separate family (*Truncatellidæ*)—comprises littoral or fresh-water Gastropods, sometimes semi-terrestrial in habit, and related on the one hand to *Acicula*, and on the other hand to the *Rissoidæ*. The nature of the breathing-organs has not been clearly ascertained. The shell in *Truncatella* is elongated and cylindrical, often truncated in the adult state, and with an entire oval aperture. Species of the genus have been detected in the Tertiary deposits, the oldest appearing in the Eocene.

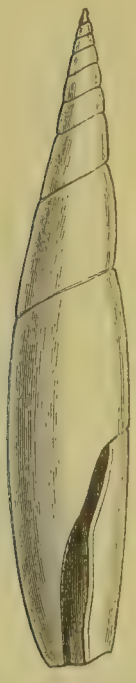


Fig. 689.—*Subulites terebriformis*, Silurian, North America. (After Hall.)

Family 31. Subulitidæ.—In this family the shell (fig. 689) is elongate and fusiform, with a smooth surface. The aperture is long and narrow, and is distinctly canaliculated in front. This family includes some Palæozoic and Triassic Gastropods, of which *Subulites* is the type, in all of which the peristome is incomplete and the shell notched in front. By Lindström the members of this group are regarded as the most ancient representatives of the division of the Siphonostomatous Prosobranchs.

In *Subulites* (? = *Polyphemopsis*, Portlock) the shell is elongated, slender and fusiform, with a smooth surface and a shallow suture. The shell is thin and fragile, and is truncated or rounded in front (fig. 689). The aperture is long and narrow; the outer lip is thin, and the inner lip is involute; and there is a distinct notch in front. The range of the genus is from the Ordovician to the Carboniferous. The genus *Euchrysalis*, ranging from the Silurian to the Trias, closely resembles *Subulites* in the shape and other characters of the shell, and is, perhaps, hardly separable from the preceding. Lastly, in the Ordovician genus *Fusispira* (fig. 690) the shell is fusiform, with an elevated spire and convex whorls. The aperture is oval or elliptical, and is prolonged below into a shallow canal; while the columella is twisted, but is without folds.

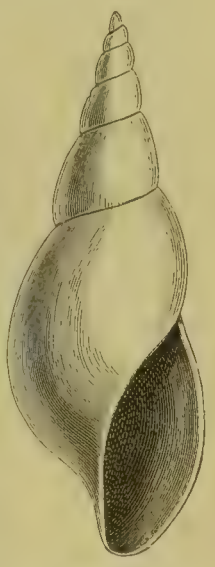


Fig. 690.—*Fusispira terebriformis*. Ordovician. North America. (After Hall.)

Family 32. Nerineidæ.—In this family the shell is turreted, thick, and solid, and the aperture is canaliculated in front. The outer lip is acute, and is sinuated superiorly or posteriorly, a slit-band which runs continuously below the suture being thus produced. The columella and parietes of the aperture are furnished with continuous folds, which are prolonged into the interior of the spire. All the members of this family are extinct, and all are confined to the Secondary period.



Fig. 691.—*Nerinea bisulcata*. Chalk. In the lower part of the specimen the shell is preserved, while the upper part shows the cast of the interior.



Fig. 692.—*Nerinea Goodhallii*, one-fourth of the natural size. The left-hand figure represents a vertical section of the shell. Coral Rag, England.

The principal or sole genus in this family is *Nerinea* itself, which has been divided into several sub-genera. In this genus the shell (figs. 691 and 692) is turreted, many-whorled, and nearly cylindrical. The columella carries continuous ridges, and similar ridges exist on the interior of the whorls, so that casts of the interior are often very unlike the exterior. The genus *Nerinea* is wholly Jurassic and Cretaceous, a very large number of species being found in the former of these systems, and particularly in strata of the age of the Coral Rag.

Family 33. Cerithiidæ.—In this family the shell (fig. 693) is spiral and turreted. The aperture is oval or quadrate, and is channelled in front, the canal being short and often bent backwards. The outer lip is generally expanded in the adult, the columella is sometimes thickened, and the operculum is horny and spiral. The members of this family are marine or live in brackish waters, some forms frequenting salt marshes or the mouths of rivers. More than three hundred recent species, and over a thousand fossil forms, of this family have been described, the most ancient types appearing in the Trias. The known forms belong to the two comprehensive genera *Cerithium* and *Potamides*, each of which has been split up into minor groups, to some of which a generic value is sometimes attached.

In *Cerithium* proper (fig. 693) the shell is without an epidermis, the operculum is paucispiral, and the aperture has a well-developed, backwardly-bent canal. The species of *Cerithium* are essentially marine, and the genus has been broken up into sub-generic groups (*Fibula*, *Eustoma*, &c.), the distinctive characters of which are mostly of small importance. The species of *Cerithium* abound in the Secondary and Tertiary rocks, and in warm seas at the present day. The oldest forms appear in the Alpine Trias.

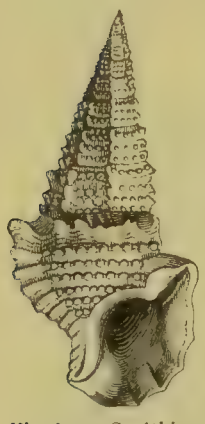


Fig. 693.—*Cerithium hexagonum.* Eocene Tertiary.

The genus *Potamides* closely resembles *Cerithium* in general characters; but the surface is covered with epidermis, the aperture has only a short canal or a notch in front, and the operculum is multispiral. The species of *Potamides* live in brackish waters or at the mouths of rivers. In the fossil condition the shells of *Potamides* cannot be certainly distinguished from those of *Cerithium*, but it is usual to consider that the representatives of this family which occur in estuarine or fresh-water deposits are referable to the former genus, while those which occur in purely marine deposits belong to the latter. On this view, the species of *Potamides* are Cretaceous, Tertiary, and Recent.

The genus has been split up into several sub-genera (*Bittium*, *Triforis*, *Ceritella*, &c.), but these are of little importance.

Family 34. Aporrhaidæ.—In this family the shell is fusiform, turreted or conical; the aperture is prolonged in front into a canal; the outer lip is expanded, aliform or digitate; and the operculum is horny. The members of this family are all marine, and they are closely allied to the *Strombidæ*. The two principal genera in this family are *Aporrhais* itself and *Alaria*.

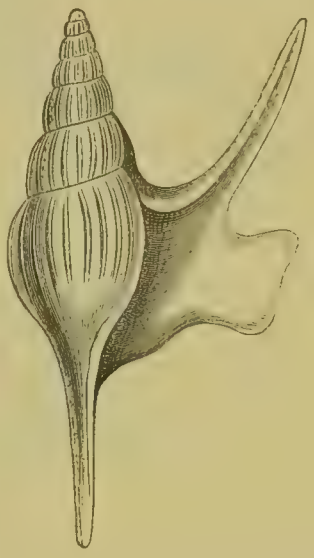


Fig. 694.—*Aporrhais Parkinsoni*. Cretaceous. (After J. Starkie Gardner.)

In *Aporrhais* (fig. 694) the shell is spindle-shaped, with a turreted spire, and the outer lip of the adult is greatly expanded and lobed, the inner lip being callous. The aperture is narrow, and is prolonged into a longer or shorter anterior canal, while its posterior angle is prolonged into an open tube, and the outer lip is sinuated in front. The genus has been broken up into numerous minor groups, and is represented by numerous Jurassic, Cretaceous, and Tertiary forms, and by a few recent species. The genus *Alaria* comprises forms with a general resemblance to *Aporrhais*; but there is no posterior canal, and the outer lip has no proper sinus in front. The species of *Alaria*, in the wide sense of the name, are confined to the Jurassic and Cretaceous deposits, being especially abundant in the former.

Family 35. Strombidæ.—In this family the shell is conical or fusiform, with a pointed spire. The aperture is prolonged into a canal in front; and the outer lip is expanded, and has a notch or sinus in front, near the canal. The operculum is horny and claw-shaped. The foot is narrow and adapted for leaping, and there is a long proboscis, with two tentacles carrying the eyes at their apices. The members of this family are all marine.

In the genus *Strombus* the shell has a short spire and a large body-whorl, and the long aperture is prolonged into a short canal in front and has a notch behind. The outer lip is expanded, and is more or less deeply indented or notched in front, near the canal. The genus is represented by a number of recent species, and by a moderate number of Cretaceous and Tertiary species.

The genus *Pteroceras* (or *Pterocera*) comprises the so-called "Scorpion-shells," in which the shell of the adult (fig. 695) has its outer lip furnished with long claws, one of which forms a posterior

canal close to the spire. Many fossil species are known, commencing in the Lias.

In the genus *Rostellaria* (fig. 696), the spire is long, and has the posterior canal running up it. Many fossil species are known, commencing in the Cretaceous rocks. The outer lip is always expanded, and in some forms is enormously so. One of the most familiar species is the great *R. ampla* (fig. 696) of the London Clay (Eocene).

Lastly, in the genus *Terebellum* (=*Seraphs*) the shell is elongated and subcylindrical, with a short or obsolete spire. The aperture is long and narrow, with a thin outer lip and a short canal. There is



Fig. 695.—*Pteroceras oceani.* Neocomian.

an emargination of the outer lip in front. The genus is Tertiary and Recent, most of the fossil forms being found in the Eocene rocks.

Family 36. Cypræidæ. — In this family the shell is spirally rolled up, but the spire is more or less completely concealed, owing to the fact that the shell becomes overlaid by a coating of enamel. The aperture is long and narrow (fig. 697), and is channelled at both ends. The outer lip is thin in the young shell, but is thickened and strongly inflected in the adult. The foot is broad, and the mantle forms lobes which meet over the back of the shell.

The principal genus in this family is *Cypræa* itself, comprising the numerous and well-known living shells commonly spoken of as Cowries. The *Cyprææ* are mainly, but not exclusively, inhabitants of warm seas, and they attain their highest development

between the tropics. A single species has been found in the highest Jurassic beds in Sicily (Zittel), but with this exception the

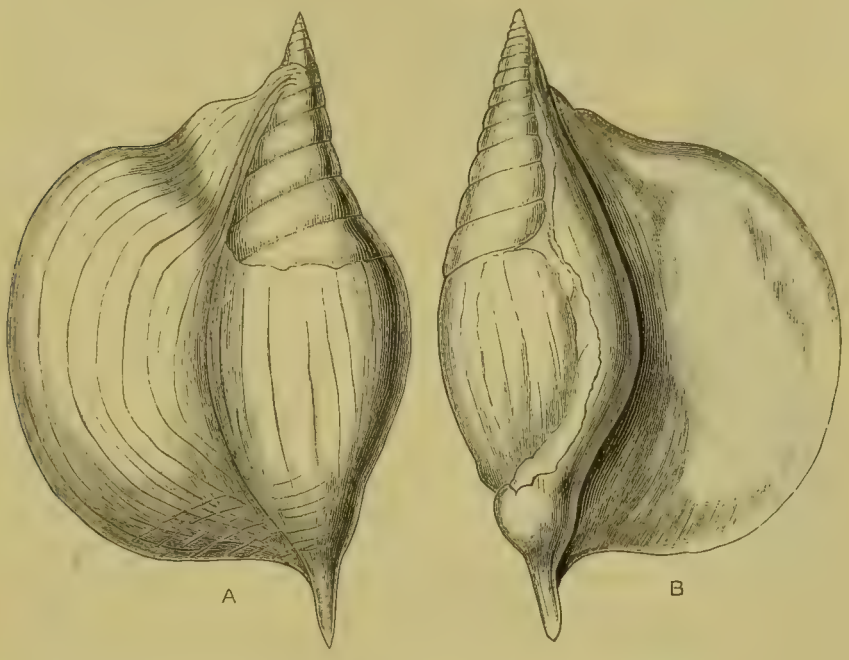


Fig. 696.—*Rostellaria ampla*, reduced one-third. Eocene Tertiary.

fossil species date from the Cretaceous period, and abound in the Tertiaries.

The shell of the Cowries in the young state is furnished with a prominent spire, and has a thin outer lip. In the adult state (fig. 697) the spire is completely concealed within the shell, the entire surface is generally covered with shining enamel, the inner lip is crenulated, and the outer lip is thickened, inflected, and crenulated. The small Cowries of which the common *Cypræa* (*Trivia*) *Europæa* is the type, are not known to occur in the Secondary rocks, but have a few Tertiary representatives. They are distinguished from the ordinary Cowries by the fact that the upper surface is adorned with transverse ribs. The genus *Ovulum* is closely related to *Cypræa*, but the aperture is drawn out anteriorly and posteriorly, and the inner lip is smooth. The genus dates from the Eocene, and possesses a number of existing representatives. *Erato*, again, ranging from

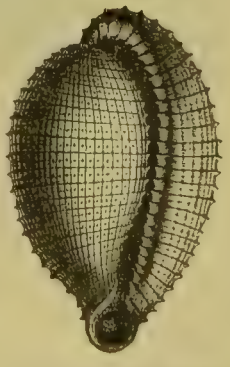


Fig. 697.—*Cypræa elegans*. Eocene Tertiary.

the Chalk to the present day, differs from the Cowries in having a cone-shaped shell, with a short but visible spire.

Family 37. Cassididæ.—In this family the shell is ventricose, with a short spire and a large body-whorl. The aperture is long and narrow, notched in front, or with a short recurved canal (fig. 698). The inner lip is callous, and the outer lip is thickened and often plaited or denticulated. The members of this family are all marine, and the oldest forms belonging to it appear in the Upper Cretaceous rocks.



Fig. 698.—*Cassis canaliculatus*. Recent.

The genus *Cassis* (fig. 698) comprises the "Helmet-shells," distinguished by their short spire, large body-whorl, elongated aperture, short recurved anterior canal, and expanded inner lip. The earliest forms of *Cassis* appear in the Eocene Tertiary, and the genus still survives. *Cassidaria* (Upper Cretaceous to Recent) closely resembles *Cassis*, but the canal is elongated and produced. Lastly, *Oniscia*, with the same range in time as *Cassidaria*, has the aperture truncated in front, with a straight canal or notch.

Family 38. Doliidæ.—In this family the shell is thick and ventricose, with a large body-whorl and a wide oval aperture. The whorls are longitudinally ribbed, and there is a short anterior canal, which may be straight or recurved. This family includes only the genus *Dolium*, the species of which are marine. The fossil forms are chiefly Tertiary, but a Cretaceous species of the genus is known.



Fig. 699.—*Ficula* (*Pyrula*) *reticulata*. Miocene Tertiary. (After Zittel.)

Family 39. Ficulidæ.—In this family the shell is thin and ventricose, spirally ribbed or cancellated (fig. 699). The aperture is of large size, and is prolonged in front into a long canal. This family includes only the genus *Ficula* (*Pyrula* in part), in which the shell is pyriform, with a very large body-whorl and a short spire, and with a sharp outer lip. The recent species of *Ficula* are inhabitants of the sea, and the earliest fossil forms of the genus appear in the Cretaceous rocks.

Family 40. Tritoniidæ.—In this family the shell is spindle-shaped, with a straight or somewhat bent canal. The whorls are often adorned with varices, and a horny operculum is present.

The members of this family are all marine, and the two principal genera contained in it are *Tritonium* (= *Triton*) and *Ranella*. The former of these ranges from the Cretaceous period to the present day, while the species of the latter are Tertiary and Recent.

Family 41. Buccinidæ.—In this family the shell is conical, with a large aperture, which is notched in front, or prolonged into a very short canal, which is reflected so as to produce a sort of varix on the back of the shell anteriorly. All the members of this family are marine, and the three most important genera comprised in it are *Buccinum*, *Nassa*, and *Eburna*.



Fig. 700.—*Buccinum glaciale*. Post-Pliocene and Recent.

The Whelks form the genus *Buccinum* (fig. 700), distinguished by the ventricose body-whorl, large aperture, and short reflected canal. Some few species of *Buccinum* are found in the Cretaceous rocks; but the genus is essentially Tertiary and Recent.

The genus *Nassa* (fig. 701) comprises the "Dog-whelks," in which the shell has a general resemblance to that of *Buccinum*, but the columellar lip is expanded and callous, and generally shows a tooth-like fold near the anterior canal. More than two hundred recent species of *Nassa* are known, and a large number of Pliocene and Miocene species have been described. In the early Tertiary deposits the genus is sparingly represented, and the oldest types appear in the Chalk.



Fig. 701. — *Nassa pusillina*. Pliocene. (After Searles Wood.)

In the genus *Eburna*, the shell is umbilicated when young, but the inner lip is callous, and in the adult condition is expanded so as to cover the umbilicus. The genus is wholly Tertiary and Recent. Lastly, the genus *Brachytrema* includes Jurassic types of the *Buccinidæ*, in which the shell is turbinated, solid, and of small size, with nodulated, ribbed, or cancellated whorls. The columella is smooth, and there is a short oblique canal. By Fischer the genus is doubtfully referred to the *Cerithiidæ*.

Family 42. Columbellidæ.—In this family the shell is ovate or fusiform, with a short spire and a large body-whorl. The aperture is long and narrow; the outer lip is thickened and toothed internally, and the inner lip is toothed or granulated in front. The members of this family are all marine, and the three principal genera

comprised in it are *Columbella* (Tertiary and Recent), *Columbellina* (Cretaceous), and *Columbellaria* (Jurassic and Cretaceous).

FAMILY 43. PURPURIDÆ.—In this family the shell is oval or fusiform, with a short spire. The columellar lip is expanded and more

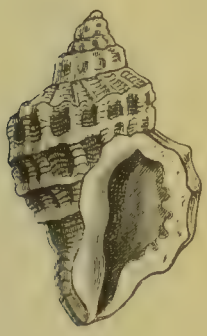


Fig. 702.—*Purpura tetragona.* Pliocene. (After Searles Wood.)



Fig. 703.—*Purpuroidea nodulata.* Jurassic. (Copied from Zittel.)

or less flattened, and there is a short anterior canal. The members of this family are all marine, and the principal genera are *Purpura*, *Purpuroidea*, and *Rapana*.

In the genus *Purpura* (fig. 702) the shell has a short spire and a large body-whorl; the columellar lip is smooth and flattened;

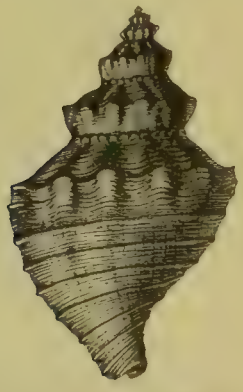


Fig. 704.—*Fusus Neocomiensis.* Lower Greensand.



Fig. 705.—*Fusus* (*Chrysodomus*) *contrarius.* Pliocene (Red Crag).

and there is a short oblique canal or notch in front. The genus is exclusively Tertiary and Recent, and the fossil forms are few in number.

In the Jurassic and Cretaceous genus *Purpuroidea* (fig. 703) the shell is oval and ventricose, with a short pointed spire and a large

body-whorl. The whorls are convex and have a row of tubercles below the suture. The outer lip is thin, the columella is smooth, and there is a short wide canal. Lastly, in *Rapana* the shell is ventricose, with a short spire, the aperture is produced in front, and the columella is umbilicated. The genus ranges from the Cretaceous to the present day.

Family 44. Fusidæ.—In this family the shell is elongated or fusiform, dextral, or sinistral, usually without varices. The aperture is moderately long, and is produced in front into a long straight canal. The operculum is horny. The members of this family are all marine, and the principal genera placed under this head by Zittel are *Fusus*, *Pisania*, *Fasciolaria*, *Turbinella*, and *Pyrula*.

In the genus *Fusus* the shell is spindle-shaped (figs. 704 and 705) and many-whorled, with an elongated straight canal. A very large number of Recent and fossil forms of *Fusus* have been recorded, and the genus has been broken up into a large number of minor groups or sub-genera, the characters of which cannot be discussed here. Using the term in its wide sense, *Fusus* ranges from the Jurassic period to the present day, attaining its maximum development in the Eocene and Miocene periods. An abundant form in the Red Crag (Newer Pliocene) is the well-known *Fusus* (*Chrysodomus*) *contrarius*, in which the shell is reversed (fig. 705). This species has now been found in the living condition. *Fusus* (*Chrysodomus*) *tornatus* is a common fossil in the Glacial deposits of Canada (fig. 706), and still survives in the neighbouring seas.

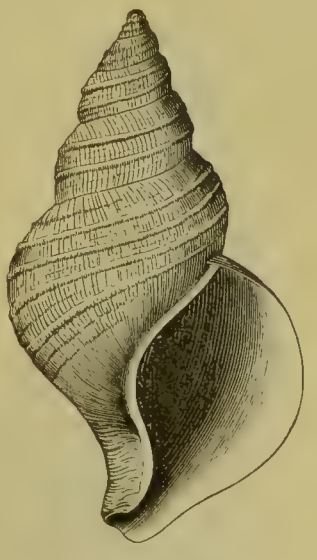


Fig. 706.—*Fusus* (*Chrysodomus*) *tornatus*, from the Glacial deposits of Canada.

In *Pisania* the shell is generally of small size, with an elevated spire and a short canal. The surface is smooth or spirally striated, and the outer lip is crenulated. The genus is exclusively Tertiary and Recent.

In *Fasciolaria* the shell is fusiform and elongated, with smooth, angulated, or tuberculated whorls. The aperture is elongated, and is prolonged anteriorly into a wide, generally straight canal. The outer lip is thin, and the columellar lip is tortuous, with several oblique folds. The genus ranges from the Chalk to the present day.

In *Turbinella* the shell is thick, with a short spire and a long straight canal, the columella having several transverse folds. Lastly,

the genera *Melongena*, *Fulgur* (fig. 707), and *Tudicla*, form portions of the old genus *Pyrula*, and all possess a pear-shaped ventricose shell, with a short spire and a large body-whorl. *Melongena* has a short wide canal and nodose or spinose whorls, and is exclusively Tertiary and Recent. *Fulgur* and *Tudicla*, on the other hand, have a long straight canal; and both genera have recent representatives, the former commencing in the Miocene, and the latter in the Cretaceous deposits.



Fig. 707. — *Fulgur canaliculatus*. Miocene.

Family 45. Muricidæ.—In this family the shell has a moderately high spire, and the surface is adorned with foliaceous expansions, spines, or well-marked varices. The aperture is round or oval, entire posteriorly, and prolonged anteriorly into a straight or slightly oblique canal, which is generally partially closed in. The members of this family are all marine, and with the exception of a few Cretaceous forms, they are confined to the Tertiary and Recent periods.

In the genus *Murex* (fig. 708) the shell is sometimes elongated, sometimes ventricose, and the surface is adorned with varices in the form of longitudinal ridges or rows of spines. The aperture is rounded, and the canal is usually greatly prolonged, and is always partially closed in. Taken in its wide sense, the genus *Murex* ranges from the Chalk to the present day, a large number of species having been obtained from the Tertiary rocks. In the nearly related genus *Typhis* (fig. 709) there are tubular spines between the varices, and the last of these lodges the posterior siphon, while the canal is completely closed in. The species of *Typhis* range from the Chalk to the present day. Lastly, in the genus *Trophon* the shell is fusiform, with numerous narrow varices, the canal being open and slightly bent to one side. The genus is Tertiary and Recent.

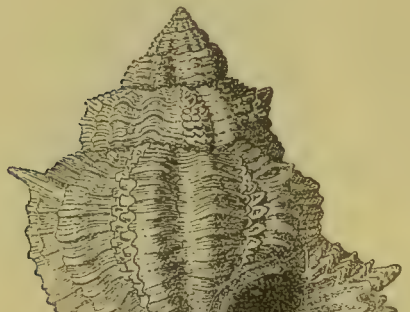


Fig. 708.—*Murex Sedgwickii*. Miocene. (After Zittel.)

Family 46. Volutidæ.—In this family the shell is turreted or convolute, with a shining, often enamelled, surface, and a large body-

whorl. The aperture is notched in front or produced into a short canal, and the columella is obliquely plaited. There is usually no operculum, the foot is very large, and the mantle is often reflected over the shell. The living members of the *Volutidæ* are chiefly inhabitants of warm seas, and are often remarkable for their brilliant colours. The family does not appear to have existed till towards the later portion of the Cretaceous period; but it is abundantly represented in the Tertiaries, and attains its maximum in existing seas. The most important genera are *Voluta*, *Volutomitra*, *Mitra*, and *Marginella*.

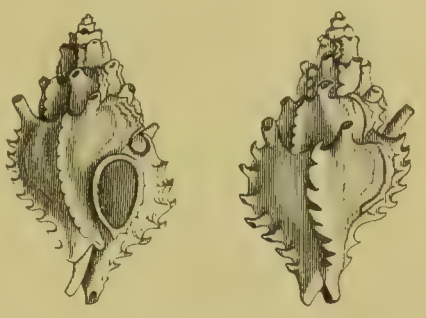


Fig. 709.—*Typhis tubifer*. Eocene Tertiary.

The true Volutes form the genus *Voluta* (fig. 710), characterised by the short spire, large, deeply-notched aperture, and columella with several plaits. A large number of recent, and still more numerous fossil, forms of *Voluta* are known, the earliest types appearing in the Cretaceous rocks. The genus has been divided into a number of sub-genera, one of the most important of which is *Volutilithes*, represented by numerous forms in the Cretaceous and older Tertiary deposits.

Mitra, *Volutomitra*, and *Turricula*, are hardly distinguishable as fossils, all of them possessing a spindle-shaped shell, with a long spire and a small aperture, an anterior notch or short canal being present, and the columella being obliquely plaited. The typical *Mitræ* have the outer lip thickened and smooth within, and are characteristic of the Tertiary and Recent periods. In *Turricula* the outer lip is striated internally, and the surface is transversely ribbed. Forms of this type range from the Cretaceous rocks to the present day. In *Volutomitra* (Tertiary and Recent) the outer lip is thin and simple.



Fig. 710.—*Voluta elongata*. Chalk.

In *Marginella*, lastly, the shell is smooth, with a short or concealed spire; and the aperture is truncated

in front, with a wide notch, a plaited columella, and a thickened outer lip. The genus is Tertiary and Recent.

Family 47. Harpidæ.—The type of this family is the genus *Harpa*, in which the shell is ventricose, with a short spire and a large body-whorl; the whorls are convex and adorned with transverse ribs, and the aperture is large and notched in front. The genus comprises marine types, and is confined to the Tertiary and Recent periods.

Family 48. Olividæ.—In this family the shell is elongated and solid, with a narrow aperture, a sharp smooth outer lip, and a callous columellar lip. The members of this family are marine, and are essentially inhabitants of warm seas.

The "Olives" (*Oliva*) and "Rice-shells" (*Olivella*) are characterised by their cylindrical polished shell (fig. 711, A), with a short spire, a long narrow aperture, notched in front, and an obliquely striated columella. The living Olives are tropical and subtropical in their distribution. A single species of *Olivella* has been detected in the Cretaceous rocks of California, but with this exception, the Olives are wholly Tertiary and Recent. The genus *Ancillaria* (fig. 711, B) is nearly related to *Oliva*, but the spire is produced, and is covered with shining enamel. Species of *Ancillaria* occur in the Upper Cretaceous rocks, but the genus is mainly Tertiary and Recent.

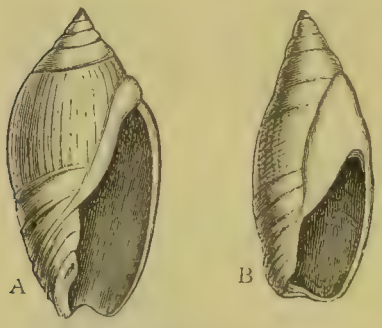


Fig. 711.—A, *Oliva Branderi*, Eocene; B, *Ancillaria glandina*, Eocene.

Family 49. Cancellariidæ.—The type of this family is the genus *Cancellaria*, in which the shell is oval or turreted, with a large body-whorl; and the aperture notched or canaliculated in front. The columella is obliquely plaited, and the surface is cancellated. The genus ranges from the Chalk to the present day.

Family 50. Conidæ.—In this family the shell is inversely conical, with a very short spire and an elongated body-whorl. The aperture is long and narrow, notched in front, the columellar lip not plaited, and the outer lip smooth and often notched at or near the suture. The members of this family are all marine, and they are principally Tertiary and Recent, the oldest types being Cretaceous.

The principal genus of this family is *Conus* itself, using this name in a comprehensive sense. The "Cones" are distinguished by their short spire and regularly conical shell (fig. 712). Very numerous recent species of *Conus* are known, and also a consider-

able number of fossil forms, the earliest representatives of the genus appearing in the Middle Cretaceous rocks. The genus *Conorbis*, of the Eocene and Oligocene, nearly resembles *Conus*, but the spire is elevated and pointed, the shell thus becoming biconical.

Family 51. Pleurotomidæ.—In this family the shell (fig. 713) is spindle-shaped, with an elevated spire and an elongated aperture, produced in front into a straight canal. The outer lip has

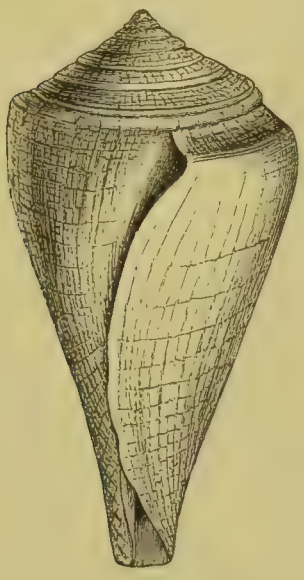


Fig. 712.—*Conus deperditus.* Eocene.

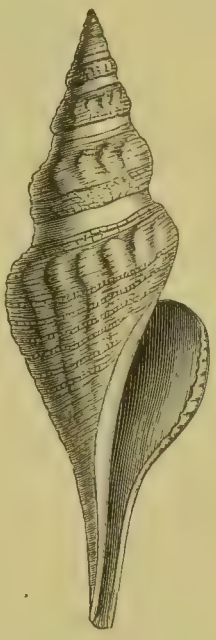


Fig. 713.—*Pleurotoma rostrata.* Eocene.

a slit or sinus posteriorly, near the suture. The principal, or sole, genus comprised in this family is *Pleurotoma* itself, which attained an enormous development in the Tertiary period, and is still very largely represented. A few forms of *Pleurotoma* are known to occur in the Cretaceous rocks; but, according to Zittel, more than nine hundred Tertiary species are known, while over six hundred and fifty recent species exist. The genus *Pleurotoma* has been divided by conchologists into a number of subordinate groups, which are sometimes regarded as subgenera, sometimes as independent genera.

Family 52. Terebridæ.—This family comprises only the genus *Terebra*, in which the shell is many-whorled and turreted, and the body-whorl is of small size. The aperture is small, and there is a short canal or notch in front; while the outer lip is thin and sharp. The living species of *Terebra* inhabit warm seas; and the oldest fossil forms appear in the Eocene Tertiary.

CHAPTER XXXIX.

DIVISIONS OF GASTROPODA—continued.

BRANCHIOGASTROPODA—*continued.*

Order II. Opisthobranchiata.

The Opisthobranchiate Gastropods are distinguished by the fact that the branchiæ are situated behind the heart, and the auricle is behind the ventricle of the heart. The gills are not usually contained in a special branchial chamber, and are commonly more or less exposed to view. The shell is wanting or present, being in the latter case often rudimentary. The sexes are united in the same individual.

The *Opisthobranchiata*, or "Sea-slugs," may be divided into two sections, the *Tectibranchiata* and *Nudibranchiata*, according as the branchiæ are protected or are uncovered. In the Nudibranchiate forms, the branchiæ, when differentiated, are placed externally on the back or sides of the body, and the animal, in the adult condition, is destitute of a shell. Owing to their want of hard structures, no traces of the Nudibranchs have ever been detected in the fossil condition. On the other hand, in the Tectibranchiate forms, the mantle more or less extensively covers the gills, and very generally secretes a shell, which may be so greatly developed as to entirely enclose the animal when withdrawn within it. Owing to their possession of a shell, the majority of the families of the Tectibranchs are known to occur in the fossil state, the earliest forms appearing in the Carboniferous rocks. The number of fossil Tectibranchiates is, however, very limited as compared with that of the Prosobranchiate Gastropods, the following four families being those which have yielded fossil representatives :—

Family 1. Actæonidæ (Tornatellidæ). — In this family the shell is spiral or convoluted ; the aperture is long and narrow, rounded or sometimes channelled in front ; and the columella is

generally plaited. The living examples of this family are mostly small and thin-shelled, but some of the fossil forms are of considerable size and are thick-shelled. The family attains its maximum in the Secondary period.

In the genus *Actæon* (*Tornatella*) the shell is ovate, with a well-marked spire, the outer lip thin, and the columella with one or more strong folds. The genus ranges from the Trias to the present day. In *Actæonina*, ranging from the Carboniferous Limestone to the present day, the shell is elongated, and the columellar lip is without folds. In *Actæonella* the shell is ventricose, with a very large body-whorl, and the columella shows three strong oblique folds in front. This genus is characteristic of the Middle and Upper Cretaceous deposits, having a remarkably wide range in space, and being sometimes represented by very numerous individuals in particular zones.

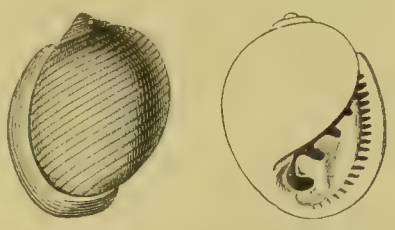


Fig. 714.—*Cinulia avellana.* Chalk.

In the genus *Cinulia* (fig. 714) the shell is globular, with a small spire; the outer lip is reflected and crenulated interiorly; and the columella exhibits toothlike folds. The genus is exclusively confined to the Cretaceous rocks. In *Cylindrites*, again, the shell is cylindrical, and smooth, with an elongated aperture and a fold on the columella. The genus ranges from the Trias to the Cretaceous rocks.

Lastly, the genus *Ringicula* (fig. 715) is now usually placed in this family. The shell in this genus is ventricose, with a small spire, the columella callous and deeply plaited, and the outer lip thickened and reflected. The earliest forms of *Ringicula* appear in the Cretaceous rocks, but the genus attains its maximum in the later Tertiaries and at the present day.



Fig. 715.—*Ringicula ventricosa.* Pliocene. (After Searles Wood.)

Family 2. Bullidæ.—In this family the shell is convoluted and thin, with a sharp outer lip and an elongated aperture. The spire is small or concealed, and the shell is often more or less completely invested by the soft parts of the animal. A large number of fossil forms of this family, beginning in the Trias, are known, and the group has attained its maximum at the present day. The three principal genera are *Bulla*, *Scaphander*, and *Cylichna*.



Fig. 716.—*Bulla suprajurensis.* Middle Oolites.

The genus *Bulla* (fig. 716) comprises the so-called "Bubble-

shells," in which the shell is ventricose, with a very large body-whorl and a deeply sunk spire. The fossil types are principally found in the Tertiary deposits. The Recent and Tertiary genus *Scaphander* is closely related to *Bulla*. Lastly, in *Cylichna* the shell is solid, and cylindrical in form, with a narrow aperture and a thickened columella. The species of this genus are numerous, and range from the Trias to the present day.

Family 3. Aplysiadæ.—In this family there is a thin horny shell, which is concealed by the reflection of the mantle over the back and sides of the animal. Two fossil species of *Aplysia* are stated to occur in the Pliocene deposits of Sicily.

Family 4. Pleurobranchidæ.—In this family the shell is limpet-like, or concealed, or may be wanting. The genus *Umbrella* appears to be represented in the Pliocene deposits, and dubious Secondary forms of the same have also been described.

Order III. Heteropoda.

The Gastropods included in the order of the *Heteropoda* or *Nucleobranchiata* differ from the typical members of the class in being *organised to lead an existence in the open ocean, locomotion being effected by a fin-like tail, or by a fan-shaped vertically-flattened ventral fin.* They are found swimming at or near the surface of the ocean ; and the body may be completely protected by a shell, within which the animal can retire, and which can be closed by an oper-



Fig. 717.—Heteropoda. *Carinaria cymbium*. *p*, Proboscis ; *t*, Tentacles ; *b*, Branchiæ ; *s*, Shell ; *f*, Foot ; *d*, Disc. (After Woodward.)

culum. In other cases, as in *Carinaria* (fig. 717), the body is large, and there is only a small shell protecting the gills and heart. In other cases, again, the shell is completely wanting. The order is divided into the two families of the *Firolidæ* and *Atlantidæ*, both of which comprise transparent delicate animals, which are either wholly naked or possess a shell of extreme tenuity and fragility.

The members of the *Firolidæ* are either shell-less, or possess a small hyaline shell, placed on the back, protecting the gills. The only member of this family which is known to be certainly represented in the fossil state is the existing genus *Carinaria* (fig. 717), a single species of which has been found in deposits of Miocene age.

In the *Atlantidæ* the animal is furnished with a well-developed but fragile shell, completely enclosing the body. In *Atlanta* itself the shell is rolled into a flat spiral, and the body-whorl is keeled, and exhibits a dorsal slit at the aperture, thus resembling the shell of the *Bellerophontidæ*. A single species of *Atlanta* has been found in the Tertiary deposits of San Domingo. Owing to the close resemblance of the shell of *Bellerophon* and its allies in external form to that of *Atlanta*, the former have been commonly regarded as Heteropods. The comparative thickness and solidity of the shell of the *Bellerophontidæ*, however, and the common association of the forms of this family with fossils of an unquestionable shallow-water type, forbid the reference of these singular Palæozoic Gastropods to the present order.

Order IV. Pteropoda.

The Pteropods or "Winged Snails" are pelagic Molluscs, found swimming near the surface in the open sea, the living forms being all of small size. They have no distinctly differentiated head, and the mouth is placed anteriorly in the centre of the fore-part of the foot, which is rudimentary. The lateral parts of the foot ("epipodia") are, however, developed into a pair of wing-like fins (fig. 718), by means of which the animal swims actively. The posterior part of the foot ("metapodium") is rudimentary, but in some cases may develop an operculum. In some groups (*Gymnosomata*) the mantle is rudimentary, and the adult is not provided with a shell. In other groups (*Thecosomata*) the mantle is well developed, and secretes a shell. In both sections of the order the embryo is furnished with a shell, but the larval shell is soon lost in the *Gymnosomata*; whereas in the great majority of the *Thecosomata*, the adult develops a secondary and permanent shell, of which the embryonic shell usually forms the initial portion. The shell of the *Thecosomata* generally is calcareous in composition, and in all the living forms is very delicate in texture. The so-called



Fig. 718.—*Cavolinia* (*Hyalæa*) *tridentata*, showing the shell, and the lateral fins attached to the sides of the head (*ff*).

"shell" of *Cymbulia* is of a cartilaginous consistence, but it does not correspond with the shell of the other Thecosomatous Pteropods in its nature or origin. In the majority of the shell-bearing Pteropods the shell is symmetrical, but in the *Limacinidæ* it is coiled into a spiral. The Pteropods are all hermaphrodite, and the young pass through a metamorphosis.

The *Pteropoda* have been very generally regarded as a distinct class of the *Mollusca;* but the most recent investigations, more especially those of Dr Pelseneer, prove that in the essential details of their organisation they do not differ materially from the *Gastropoda*, of which class they should be considered as a division or order. The Pteropods fall naturally into the two sections of the *Gymnosomata* and the *Thecosomata*, the former devoid of any shell in the adult condition, while the latter (with the exception of the aberrant genus *Cymbulia*) possess an external calcareous shell. Owing to their having no hard parts capable of preservation in the fossil condition, the Gymnosomatous Pteropods have left behind them no traces of their past existence, and therefore require no further consideration here. On the other hand, the Thecosomatous Pteropods are known to occur as fossils, though opinions differ as to the true nature of many of the organisms which have been referred here.

As regards their *distribution in time*, the Tertiary rocks have yielded the remains of indubitable Pteropods, which differ in no respects from existing forms, and are, in fact, largely referable to existing genera. The whole series of the Secondary rocks has, on the other hand, yielded no remains of organisms which can be asserted to be unequivocal Pteropods. It is not, indeed, till we reach the Devonian and Silurian deposits that we meet with fossils which in all essential respects agree with the living Pteropods, and which appear to belong to such existing genera as *Styliola* (*Creseis*). It is true that these ancient representatives of *Styliola* have had their claim to be regarded as Pteropods strongly disputed, but it will be pointed out hereafter that there is at present no sufficient ground for denying their Pteropodal nature. The case, however, is different with the three remarkable groups of fossils typified respectively by the genera *Tentaculites*, *Hyolithes*, and *Conularia*, the age of which is exclusively or mainly Palæozoic. These ancient types differ in many respects from the typical Pteropods, and their true nature and position must be regarded in the meanwhile as more or less open to question. If these aberrant and problematical genera be provisionally included among the Thecosomatous Pteropods, the following are the principal families included in this division of the order :—

Family 1. Limacinidæ.—In this family the shell is twisted into

a left-handed spiral, and a spiral operculum is present. The anus is on the right side, and the pallial cavity is dorsal in position. It is not certain that any fossil forms of this family have been detected, but some minute shells from the Eocene, Miocene, and Pliocene deposits have been referred with considerable probability to the existing genus *Limacina* (*Spirialis*).

Family 2. Cavoliniidæ.—In this family the shell is bilaterally symmetrical and is not rolled up into a spiral. The anus is on the left side, and the pallial cavity is ventral. The shell has a variable form, but is essentially a hollow cone, which may be flattened dorso-ventrally or may be circular in section. The initial portion of the shell is generally distinct from the rest, and represents the larval shell (Pelseneer).

The types which have been described under the names *Creseis*, *Hyalocylix*, *Clio* (*sensu restricto*), and *Styliola*, are included by Dr Pelseneer under the common generic name of *Clio* (= *Cleodora*). In all these forms the shell (fig. 722, c) is a conical tube, sometimes circular in outline, sometimes oval, sometimes laterally keeled, the apex of the shell being pointed, or exhibiting a bulbiform enlargement due to the presence of a distinctly defined embryonic shell. Unquestionable remains of this group of Pteropods are found in the Miocene and Pliocene deposits.

In the Silurian and Devonian rocks of both the Old and New Worlds there occur minute conical calcareous tubes, which have been generally referred to *Styliola* or *Creseis*. As the type of these may be taken *Styliola* (*Creseis*) *fissurella* of the Devonian rocks of North America. In this remarkable form (fig. 719) the shell is a very delicate calcareous tube, of a conical form, circular in section, and without internal partitions, either longitudinal or transverse, the average length of the tubes being from one to three millimetres. The apex of the tube is commonly slightly bulbous (fig. 719, A), and is thus marked off as an "initial chamber" from the rest of the shell. The surface is without annulations, and may be smooth, or marked by fine transverse striæ, sometimes with longitudinal striæ as well (fig. 719, B). *Styliola fissurella* is exceedingly abundant in parts of the Devonian rocks of North America, and sometimes gives rise by the accumulation of its shells to thin bands of limestone (fig. 720), which may have a considerable geographical range. Dr Pelseneer

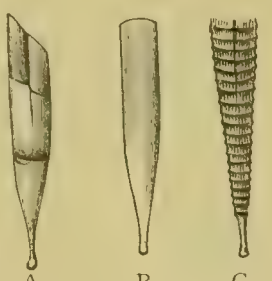


Fig. 719.—A and B, Specimens of *Styliola* (*Creseis*) *fissurella*, Hall, from the Devonian rocks (Hamilton Group) of North America, enlarged about six times, showing the embryonic shell at the apex; C, Apical portion of the tube of *Tentaculites gracilistriatus*, from the same formation, enlarged to show the embryonic shell. (After Hall.)

denies that the so-called "Styliolæ" of the Silurian and Devonian rocks can be referred to the *Pteropoda* on the grounds of their great size, the absence of an embryonic shell, and the fact that no existing species of *Clio* has the shell longitudinally striated. The first two of these objections, however, do not apply to *Styliola fissurella* and its allies, since the tube is smaller than that of some of the existing species of *Clio*, and an embryonic shell is present; while the third objection would appear to be of anything but a conclusive character. It is certainly remarkable that, admitting the Pteropodal nature of *Styliola fissurella*, no traces of forms of the same genus should have hitherto been met with in the later Palæozoic and in the Secondary deposits, and that the genus is not known to be again represented till the Miocene period is reached. Palæontology, however, is rich in examples of gaps of this kind, and little importance can be attached to a seeming hiatus, which may any day be partially filled up.



Fig. 720. — Thin section of limestone from the Devonian rocks of Canandaigua, North America, composed almost entirely of the tubes of *Styliola fissurella*, enlarged twenty times. (Original.)

Of the remaining genera of the *Cavoliniidæ*, *Cuvieria* has a straight conical shell, the hinder pointed half of which is generally caducous in the adult. The genus is represented by existing species and by late Tertiary types. Lastly, in *Cavolinia* (*Hyalæa*) the shell (fig. 721) is globular, the dorsal plate comparatively flat, and prolonged into a hood, the ventral plate bulging and convex, the aperture contracted, with a lateral slit on each side, and the hinder end with one to three spines. The genus is represented by Miocene and Pliocene forms as well as by existing species.



Fig. 721.—*Cavolinia* (*Hyalæa*) *Orbignyana*. Miocene Tertiary.

Family 3. Cymbuliidæ.—This family includes only the recent genus *Cymbulia*, which differs from all the other Thecosomatous Pteropods in the possession of a straight, bilaterally symmetrical, cartilaginous "pseudoconch," which is formed by the thickening of the integument, and is not homologous with the shell of the ordinary Pteropods. As the "shell" of *Cymbulia* is not capable of preserva-

tion in the fossil state, no record of the past existence of the genus can be obtained.

Family 4. Hyolithidæ.—With this family we enter upon the consideration of a series of remarkable Palæozoic fossils, which have been generally referred to the *Pteropoda*, though their true affinities cannot be considered as certainly established. The type of this family is the genus *Hyolithes* (= *Theca* and *Pugiunculus*), which has been generally regarded as allied to the recent *Clio* or *Styliola* (fig. 722, c), though the dimensions of the shell much exceed those of the ordinary species of the latter, and there are other differences as well. The shell (fig. 722, d, f, h) in *Hyolithes* is bayonet-shaped or conical, usually straight, but sometimes curved,

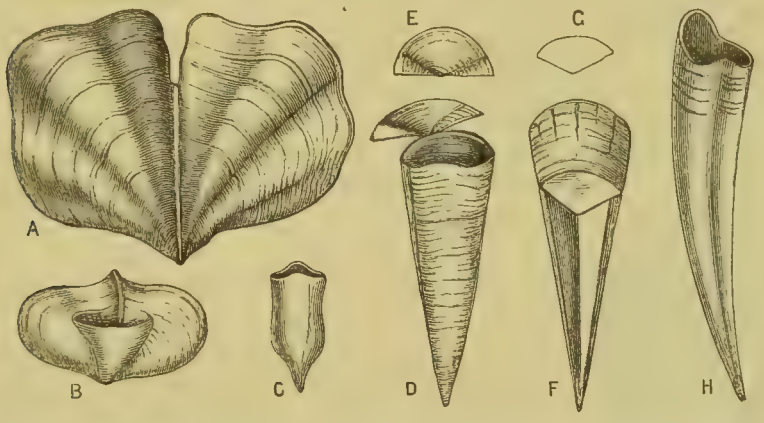


Fig. 722.—a, *Pterotheca corrugata*—Ordovician (after Salter); b, *Pterotheca transversa*—Ordovician (after Salter); c, *Styliola* (*Clio*) *depressa*—Miocene; d, *Hyolithes* (*Theca*) *operculatus*; and e, its operculum—Upper Cambrian (after Salter); f, *Hyolithes aratus*—Upper Cambrian; and g, Cross-section of the same (after Salter); h, *Hyolithes acutus*—Silurian (after Eichwald).

of thin texture, transversely striated or smooth, sometimes with marginal ribs, but without lateral appendages. The mouth of the shell is trigonal, and in some forms, at any rate, is provided with an operculum (fig. 722, e), or occasionally furnished with curved lateral appendages. The length of the shell varies, but is commonly from an inch to an inch and a half. The species of *Hyolithes* are most abundant in the Upper Cambrian and Ordovician rocks; but there are various Silurian and Devonian forms, and the genus is recorded as occurring in both the Carboniferous and the Permian rocks. *Pterotheca* (fig. 722, a and b), of the Ordovician, in many respects resembles *Hyolithes;* but the median dagger-shaped shell is bordered by lateral concentrically-striated expansions or alations, thus coming to superficially resemble the carapace of certain of the Phyllopods.

The Devonian genus *Coleoprion* has a cylindrical and conical

shell, the exterior of which is marked with chevron-shaped striæ. Possibly allied to the preceding types, but of wholly uncertain affinities, are the genera *Hemiceras* and *Salterella*. In the first of these are conical elongated shells, of circular section, in which the walls are thickened by the deposition of concentric calcareous lamellæ, till only a small tubular space is left in the centre. The genus is Ordovician. *Salterella*, of the Upper Cambrian and Ordovician rocks, comprises conical tubes, resembling the preceding in shape, but consisting of several hollow cones placed one within the other.

Family 5. Conulariidæ.—This family includes only the remarkable genus *Conularia* (fig. 723), the true relationships of which have not been clearly established, though the genus is usually placed among the *Pteropoda*. The shell in *Conularia* is very thin, and is pyramidal in shape, the transverse section being rhomboidal or four-sided. The apex is often deciduous, and the internal cavity may be partitioned off near the apex by one or more transverse plates. The aperture of the shell is contracted, and is partially closed by tongue-like prolongations from its corners. Each of the four faces of the shell may be provided along its entire length with an internal median longitudinal fold, sometimes with two such, but these may be wanting or rudimentary. Externally, each face of the shell is divided into two equal halves by a longitudinal groove, corresponding with the internal fold above mentioned; and the surface is ornamented with transverse, smooth, or tuberculated ridges, which are angulated in the middle line of each face, so as to form a series of obtuse angles, the apices of which point towards the aperture.

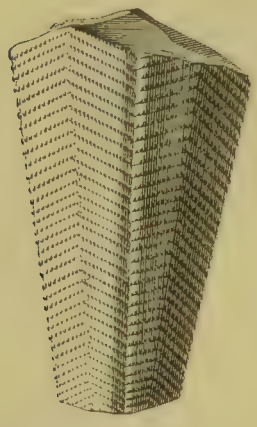


Fig. 723.—*Conularia ornata*. Devonian.

The genus *Conularia* attains its maximum in the Ordovician and Silurian rocks, some of these early types attaining a length of nearly a foot, with a breadth of more than an inch. The Devonian and Carboniferous rocks have yielded a few species, and two forms occur in the Permian, while a single species has been detected in the Trias, and another has been recorded from the Lias.

Family 6. Tentaculitidæ.—This family comprises only the genus *Tentaculites*, in which the shell (fig. 724) is comparatively thick and solid, and has the form of a straight, elongated, conical tube, from half a centimetre up to three centimetres in length, which tapers to a closed apex at one end, and expands towards the other to a circular aperture. The tube is always circular in outline, and

the apex is often partially filled up with a secondary calcareous deposit, or may be partitioned off by one or more curved transverse plates (fig. 725, A). The initial portion of the shell may be smooth and without annulations, and may be simply pointed. In other cases, the apex is distinctly bulbiform (fig. 719, C), its starting-point being a dilated chamber, which appears in no respect to differ from the "embryonic shell" of *Clio* and other Pteropods. The whole of the tube, except the initial portion, is annulated by abruptly elevated rings, which become more remote as the aperture is approached; and the surface between the annulations is marked by fine encircling striæ, sometimes accompanied by longitudinal striæ as well.

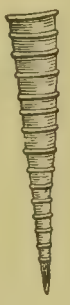


Fig. 724.—*Tentaculites ornatus*. Silurian.

As regards its minute structure, thin sections show that the tube of *Tentaculites* is composed of two distinct layers of a different nature (fig. 725, B and C). The outer layer is very dense, and is thickened at intervals so as to form the annulations which are so characteristic of the genus. The inner layer is composed of transparent calcite, traversed by parallel lamellæ of a dark colour, which are approximately parallel to the surface of the tube. Both layers



Fig. 725.—Minute structure of *Tentaculites attenuatus*, from the Devonian rocks (Hamilton Group) of Canada. A, Section of the apex of a tube, showing curved transverse partitions; B, Transverse section of the tube (the oval form of the tube is the result of pressure); C, Vertical section, taken through the middle of the tube; D, Vertical section traversing the wall of the tube, and showing its peculiar tubulated structure. The figures are enlarged about twenty times. (Original.)

are more or less extensively penetrated by a system of exceedingly minute tubuli (fig. 725, D), the direction of which is approximately at right angles to the surface.

The genus *Tentaculites* ranges from the Ordovician to the Devonian, occurring for the most part in limestones, and being often present in vast numbers in particular beds. In no case is the shell attached to any foreign body.

The affinities of *Tentaculites* cannot, in the present state of our knowledge, be determined with absolute certainty. The compara-

tive thickness and solidity of the shell, together with its remarkable minute structure, must be considered as points which militate against a reference of the genus to the Pteropods. On the other hand, its free habit of existence, its general form, its mode of occurrence, and its occasional possession of a distinct initial chamber or embryonic shell would support the view that it belongs to the *Pteropoda*. The occasional presence of curved internal septa is a point of small weight, one way or the other, since such transverse partitions are not absolutely unknown in recent Pteropods (*Cuvieria*). Still less stress can be laid upon the argument that *Tentaculites* can hardly be regarded as a Pteropod, seeing that the normal forms of the *Pteropoda* do not make their appearance till the Tertiary rocks are reached. Any weight that might be supposed to be carried by such an argument is counterbalanced by the fact that in *Styliola fissurella* and its allies we have Palæozoic forms which have not been shown to differ materially from existing types of Pteropods. By some palæontologists *Tentaculites* is regarded as belonging to the Tubicolar Annelides; and *casts* of the shell of *Tentaculites* are undoubtedly very similar to casts of the tube of *Cornulites*. The microscopic structure of the tube of *Tentaculites* is, however, widely different from that of *Cornulites*, while the tube shows no signs of having been at any time of life attached to any foreign body. It is, however, quite possible that *some* of the forms which have been referred to *Tentaculites* are really Annelidan in nature. Thus, Hall has pointed out that all the forms from the Ordovician rocks of North America which have been placed in *Tentaculites* are *curved* and are longitudinally striated; and he regards these, therefore, as probably truly belonging to *Cornulites* or to some related Annelidan genus.

Sub-Class II. Pulmogastropoda.

The Pulmonate Gastropods are essentially distinguished by the fact that the breathing-organ is a pulmonary chamber, formed by an inflection of the mantle, to which air is directly admitted by an external aperture; while the sexes are united in the same individual.

The most typical members of this division of Gastropods; such as the Land-snails and Slugs, are terrestrial in habit. Others, like the *Limnæidæ*, inhabit fresh waters, and either come to the surface to obtain air, or, in some cases, have the power of using the lung-chamber as an organ of aquatic respiration. A few forms only (*Siphonariidæ*, *Gadiniidæ*) are inhabitants of salt water.

The condition of the shell varies much, a few forms (*e.g.*, *Oncidium*) being wholly without a shell. In the Slugs, a shell is present, but is of small size, and is concealed within the mantle. In the ordinary Snails, again, and in the Pond-snails, there is a well-

developed external shell, within which the animal can entirely withdraw itself.

As regards their *distribution in time*, the completely shell-less forms are necessarily altogether unknown in the fossil condition, and the forms with a rudimentary and concealed shell are only known in the latest Tertiary deposits. The abundance of the ordinary shell-bearing forms as fossils depends mainly on the habits of the animal. As the preservation of an ancient land-surface in the crust of the earth is a matter of rare occurrence, the strictly terrestrial Pulmonates are not largely represented in the fossil state, their remains, in fact, occurring principally in lacustrine or fluviatile deposits intermingled with the shells of fresh-water types of Pulmonates. These latter are found in moderate numbers in fresh-water deposits of Secondary and Tertiary age. The oldest known types of the Pulmonate Gastropods have been found in the Carboniferous rocks.

The sub-class *Pulmogastropoda* may be divided into the two orders of the *Stylommatophora* and the *Basommatophora ;* but only a few of the more important families composing these can be noticed here.

Order I. Stylommatophora.

The Pulmonates included in this order have the eyes placed at the extremities of long feelers, which are retractile and capable of invagination. The shell may be rudimentary or even absent, but is usually well developed. The following are, from a palæontological point of view, the most important families included in this order :—

Family 1. Testacellidæ. — This family includes carnivorous Pulmonates, with a spiral shell of very variable size. In *Testacella* itself, the animal is slug-like, and there is a minute ear-shaped shell placed at the hinder end of the body. Fossil forms of this genus have been found in the later Tertiary deposits.

In *Glandina*, on the other hand, there is a well-developed spiral shell, within which the body of the animal can be withdrawn. The recent types of this genus inhabit warm regions, and the fossil forms date from the Upper Cretaceous period.

Family 2. Limacidæ.—In this family are comprised the "Slugs," in which there is a minute rudimentary shell concealed within the mantle. Species of *Limax* have been recognised as occurring in the late Tertiary and Quaternary deposits.

Family 3. Helicidæ.—This family includes the ordinary "Land-snails," in which there is a well-developed shell, capable of containing the entire animal. A large number of fossil representatives of this family are known, chiefly belonging to the Tertiary period, but

occurring also in deposits of Secondary age, and even in rocks as old as the Carboniferous formation. If *Dawsonella* be regarded as a member of the *Helicinidæ* (see p. 778), the oldest representatives of the *Helicidæ* are the *Zonites* (*Conulus*) *priscus* and the *Pupa* (*Dendropupa*) *vetusta* of the Coal-measures of North America, both of which were first discovered and described by Sir William Dawson.

In the genus *Helix* are the ordinary Land-snails, of which about two thousand living species are known, belonging to a large number of subgeneric groups. The shell in *Helix* is very variable in shape, sometimes conical, sometimes depressed, and sometimes discoidal; the aperture being transverse, crescentic or rounded in shape, and the columella being perforated or imperforate. The most ancient of the typical *Helices* appear in the Eocene rocks, and a large number of Tertiary species have been recognised.

In *Zonites* the shell is thin, usually hyaline, in the form of a

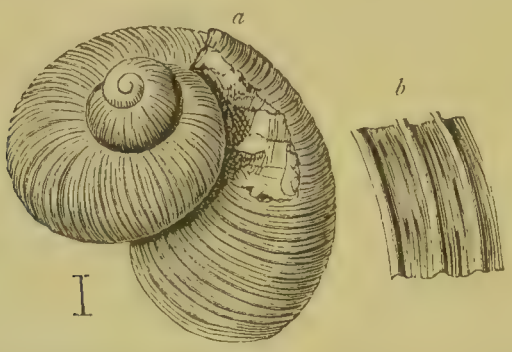


Fig. 726.—*Zonites* (*Conulus*) *priscus* (after Dawson). *a*, Specimen enlarged twelve diameters; *b*, Sculpture, magnified. Coal-measures, Nova Scotia.

depressed spiral, with a simple and sharp-edged peristome, and almost always umbilicated. The oldest example of this genus is the *Z. priscus* (fig. 726) of the Coal-measures of Nova Scotia. Other species occur in the later Tertiaries; and the *Archæozonites* of the Oligocene and Miocene deposits is nearly related to *Zonites*.

In *Bulimus* the shell is oval or turreted, the columella is straight, the aperture is oblong, and the outer lip is expanded and thickened. *Bulimulus* includes forms with a shell very similar to that of *Bulimus*, but with a generally thin lip and an elongated aperture. The earliest forms of *Bulimus* appear in the Upper Cretaceous rocks. In the genus *Achatina* the shell is like that of *Bulimus*, but the columella is twisted. No undoubted fossil representatives of this genus have been recognised.

In the genus *Clausilia* the shell is spindle-shaped, and is coiled into a left-handed spiral, the aperture being elliptical, and partially contracted by two folds of the inner lip. The mouth of the shell

is closed when the animal is withdrawn within it by a movable calcareous plate ("clausilium"). A large number of recent species of *Clausilia* are known, but the fossil forms are not numerous, and the oldest of them appear in the Eocene.

In the genus *Pupa* the shell is cylindrical or oblong, with a rounded, often toothed aperture and a reflected outer lip. The oldest known type of this genus is the *Pupa* (*Dendropupa*) *vetusta* of the Coal-measures of Nova Scotia, discovered by Sir William Dawson in the hollow trunk of an erect *Sigillaria*. The aperture in this form (fig. 727) is devoid of teeth. An allied type is the *Pupa vermilionensis* of the Coal-measures of the United States. With these exceptions, the fossil *Pupæ* are all of Tertiary age.

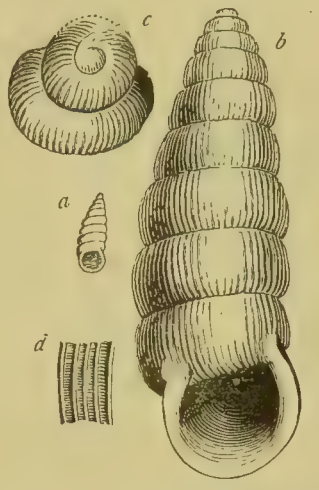


Fig. 727.—*Pupa* (*Dendropupa*) *vetusta* (after Dawson). *a*, Natural size; *b*, Enlarged; *c*, Apex enlarged; *d*, Sculpture, magnified. Coal-measures.

Lastly, in the genus *Succinea* the shell is thin and ovate, with a small spire and a large body-whorl, the aperture large and obliquely oval, and the outer lip thin. The "Amber-snails" live in moist places on land, and the known fossil species are confined to the Tertiary rocks. *S. oblonga* and *S. putris* are very common in the Loess.

Order II. Basommatophora.

In this order of Pulmonates the eyes are placed at the base of two feelers, which are contractile, but are not capable of invagination. Of the families of this order, the *Auriculidæ* and *Limnæidæ* are inhabitants of fresh waters, or are amphibious, or in other cases live in moist places on land, while the aberrant groups of the *Siphonariidæ* and *Gadiniidæ* are marine in habit.

Family 1. Auriculidæ.—In this family the shell is spiral, with a horny epidermis; the aperture is elongated, generally with a toothed outer lip; and the columella is folded. The members of this family inhabit salt-marshes and places overflowed by the sea. The principal genus is *Auricula* itself, which ranges from the Upper Jurassic rocks to the present day, but the fossil forms are of comparatively little importance.

Family 2. Limnæidæ.—In this family the shell is well developed, thin and horn-coloured, and of very variable shape. The aperture is simple, and the outer lip is sharp. The *Limnæidæ* are all in-

habitants of fresh water, and they are found in fluviatile and lacustrine deposits. They commence in the Jurassic period, members of this family having been described from the Lias (?) and from the Purbeck beds (Upper Jurassic). It is not, however, until we reach the base of the Cretaceous system (Weald Clay) that these forms appear in any abundance.



Fig. 728.—*Limnæa pyramidalis.* Eocene.

The genus *Limnæa* (fig. 728) includes the so-called "Pond-snails," characterised by their thin, spiral, elongated shells, with a large body-whorl and an obliquely-twisted columella. The species of this genus commence in the Upper Jurassic (Purbeck Beds), and they are abundantly represented in the Tertiary series.

In the genus *Physa* (fig. 729) the shell is left-handed ("sinistral"), ovate, thin, and polished, with the aperture rounded in front. Walcott has described a species of *Physa* as occurring in the Lower Carboniferous rocks of Nevada. With this exception, the oldest species of the genus occur in the Purbeck beds (Upper Jurassic) and Wealden (Lower Cretaceous). Most of the fossil species, however, belong to the Tertiary period, and the genus attains its maximum at the present day.

The genus *Planorbis* (fig. 730, A and B) comprises a number of well-known fresh-water shells, in which the shell is discoidal and



Fig. 729.—*Physa columnaris.* Eocene.

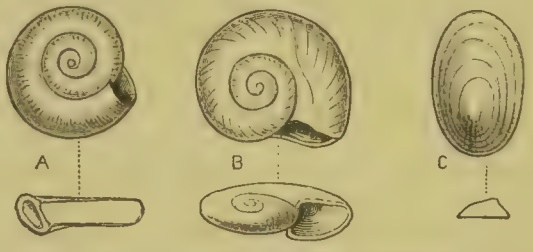


Fig. 730.—A, *Planorbis complanatus*, viewed from below and in front—Pliocene and Recent; B, *Planorbis discus*—Eocene—viewed from above and in front, reduced one-half; C, *Ancylus Matheroni*—Tertiary—viewed sideways and from above, the latter figure enlarged.

many-whorled, the aperture crescentic, and the lip thin. The fossil species of this genus date from the Lias (?), but are not plentiful except in the Tertiary deposits, from which numerous forms have been obtained.

Lastly, the genus *Ancylus* (fig. 730, C) comprises the so-called "River-limpets," distinguished by their thin limpet-shaped shell, the apex of which is approximated to the hinder margin. The fossil species are few in number, and the earliest forms appear in the Miocene deposits.

Family 3. Siphonariidæ.—This family comprises certain marine Gastropods, of amphibious habits, which agree with the normal Pulmonates in the possession of a pulmonary chamber. The shell is limpet-shaped, unsymmetrical, and usually radially ribbed. The muscular impression in the interior of the shell is interrupted by a lateral sinus corresponding with the opening of the pulmonary sac. The type-genus of this family is *Siphonaria* itself, the living species of which are found in tropical seas. The earliest fossil forms appear in the Eocene deposits, but the shell is with difficulty distinguished from that of the *Patellidæ*.

Family 4. Gadiniidæ.—This family comprises marine Pulmonates, which possess a patelliform shell, and differ from the preceding family only as regards the armature of the mouth. No undoubted fossil forms of the family are known, but Professor von Zittel is disposed to refer here the genus *Valenciennesia*, in which the shell is like that of a large limpet, but the apex is much incurved, and an internal sulcus and corresponding superficial fold extend from the apex to the right margin, and exist in a less developed form on the left side. This remarkable genus occurs in abundance in the brackish-water Upper Miocene deposits ("Congeria-beds") of south-eastern Europe.

CHAPTER XL.

POLYPLACOPHORA AND SCAPHOPODA.

Class III. Polyplacophora.

The class of the *Polyplacophora* comprises only the family of the *Chitonidæ*, which differs in many important respects from the Gastropods, and presents certain relationships with the Worms. The body in the *Chitonidæ* (fig. 731, A) is elongated and worm-like, bilaterally symmetrical, with the mouth at the anterior end, and the anus at the hinder extremity of the body. There is no differentiated head, nor are cephalic tentacles developed. The under surface of the foot forms a creeping disc; and the gills are numerous (fig. 731, *g*), and are contained in an imperfect pallial chamber or groove, between the margins of the foot and the edge of the mantle. The upper surface of the body is covered by the mantle, which secretes a "multivalve" shell (fig. 731, B), composed of eight transverse imbricated plates, which succeed one another from before backwards, and are embedded in the leathery or fibrous border of the mantle.

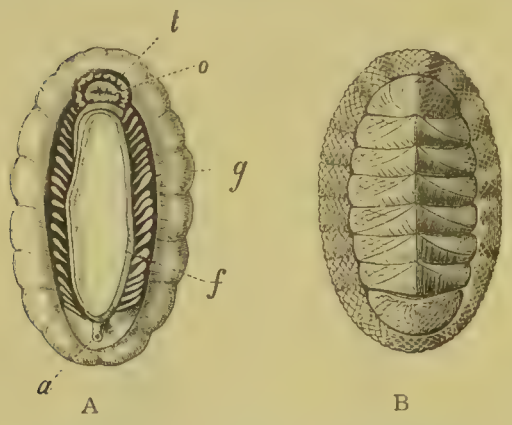


Fig. 731.—A, Under surface of a species of *Chiton* (after Cuvier): *t*, Fringe of tentacles round the mouth (*o*); *g*, Branchiæ; *f*, Under surface of foot; *a*, Anus. B, Shell of *Chiton squamosus*, reduced one-half. (After S. P. Woodward.)

The shell of the Chitons (fig. 731, B, and fig. 732) consists of eight valves placed in a line, the anterior or "cephalic" valve and the posterior or "anal" valve invariably differing from the six "intermediate" valves, which are similar to one another. Each of the intermediate valves is divisible by lines of sculpturing into a central

area (fig. 732, B, *m*) and two lateral areas (*l*). The upper or exposed surface of the valves is spoken of as the "tegmentum," while the "articulamentum" is a peripheral zone which supports and is partly covered by the tegmentum. The shell is entirely surrounded by, and more or less extensively embedded in, the "girdle" or "zona" formed by the border of the mantle, and variously covered on its upper surface with scales, spines, or bristles. The cephalic and the six intermediate plates have their apices at their posterior margin, but the apex of the anal plate is usually anterior.

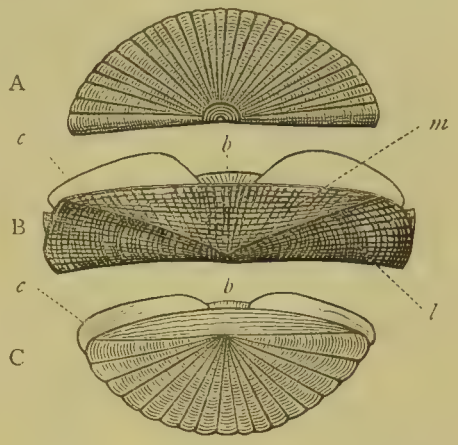


Fig. 732.—A, Cephalic valve, B, one of the intermediate valves, and C, anal valve of *Chiton magnificus*, viewed from the dorsal aspect: *m*, Central area of the valve; *l*, One of the lateral areas of the valve; *c c*, Apophyses or sutural laminæ; *b b*, Sinus and jugal area. (After Gray.)

The cephalic valve is usually semicircular in shape, and its front edge is generally prolonged into an "insertion-plate," or forward extension of the "articulamentum," by which it is embedded in the mantle. The intermediate valves are transverse in shape as a rule, and their front edges are furnished with forward extensions of the articulamentum, which serve to unite the successive valves, and are known as the "apophyses" or "sutural laminæ" (fig. 732, *c*). Posteriorly the intermediate plates usually possess "insertion-plates." The anal valve is variable in form and sculpturing, as well as in the position of its apex, but it has in front a pair of apophyses, separated by a median sinus (*b*), and it possesses an insertion-plate posteriorly. The insertion-plate of the anal valve may be similar in form to that of the cephalic valve, or may be different from it, and by this character the Chitons are grouped as "regular" or "irregular."

The tegmentum of the recent Chitons exhibits two sets of superficial circular apertures, one set large ("megalopores"), the other set of much smaller size ("micropores"). These apertures lead into corresponding sets of tubes, large and small, which perforate the shell vertically, and open below into a plexus of horizontal canals running in the space between the apposed surfaces of the tegmentum and articulamentum. These horizontal canals open internally, and lodge processes derived from the mantle, which send out ramifications into the canals connected with the "megalopores" and "micropores." These ramifications finally expand into differently-sized papilliform bodies ("megalæsthetes" and "micræsthetes"), which appear to be peculiar organs of touch. Further, as shown by Moseley, a number of the "megalæsthetes" are in some cases spe-

cially modified in structure, and become converted into minute eyes which are distributed over the exposed surface of the tegmentum.

The Chitons are inhabitants of the sea, and they are of rare occurrence as fossils, being more abundant in the Palæozoic than the Mesozoic or Kainozoic deposits. Under the name of *Holochiton*, Fischer has united the recent genus *Leptochiton* and a number of Palæozoic types which have been placed in groups under special names (*Helminthochiton*, *Gryphochiton*, &c.) The general characters of the "Holochitons" are the possession of an oval or elongated shell, in which the "insertion-plates" are obsolete or more or less developed, their margins being in the latter case entire, and showing neither fissures nor denticulations. Taken as a whole, the Palæozoic Chitons are characterised by the elongated form of the shell, the narrowness of the valves (fig. 733), the absence or rudimentary condition of the insertion-plates, and the widely separated sutural laminæ. In their narrow valves and elongated form the Palæozoic Chitons resemble the recent genus *Cryptoplax* (= *Chitonellus*), but the shell in the latter is formed wholly by the articulamentum, the valves are more or less separated, and the insertion-plates have fissured margins. As regards their geological distribution, the "Holochitons" range from the Ordovician to the Permian rocks, but the majority of the known forms are Carboniferous. Some of the Carboniferous types, however, possibly belong to *Cryptoplax* (*Chitonellus*). The conical calcareous plates of the Silurian rocks of Gotland, which have been described under the name of *Chelodes*, are regarded by Lindström as referable to the *Chitonidæ*. The plates of *Chelodes* show remarkable resemblances to those of the Chitons, but they are altogether peculiar in the fact that not only are there no insertion-plates, but the sutural laminæ are also wholly unrepresented.

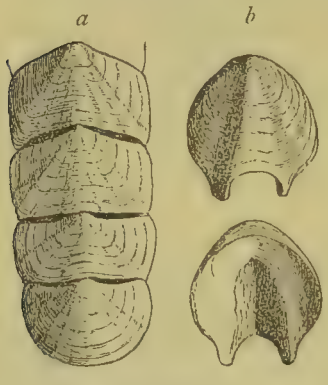


Fig. 733.—*Holochiton* (*Gryphochiton*) *priscus*, from the Carboniferous Limestone of Belgium. *a*, Four consecutive plates; *b*, Anal plate seen from the exterior and from the interior. (After De Koninck—copied from Zittel.)

But few representatives of the *Polyplacophora* have hitherto been found in the Secondary and Tertiary rocks, and these few appear to belong to the genus *Chiton* itself, in which the insertion-plates are well developed and possess fissured margins, those of the cephalic and anal valves being alike in form.

Class IV. Scaphopoda.

This class of Molluscs includes only the single family of the *Dentaliidæ*, the characters of which would assign to it a position in some respects intermediate between the Lamellibranchs and the Gastropods. The type of the group is the genus *Dentalium*, the animal of which is bilaterally symmetrical, and is enclosed in a continuous mantle, which secretes a tubular shell, which is open at both ends. From the large anterior aperture of the shell is protruded the foot, with a circle of tentacles surrounding the mouth, but there is no distinct head. The oral tentacles appear to discharge a respiratory function, but there are no specialised branchiæ, nor is a definite heart present. The nervous system is of the Molluscan type; the kidneys are paired; the sexes are distinct; and the pharynx is furnished with a radula.

The shell in the *Dentaliidæ* is in the form of a slightly curved calcareous tube (fig. 735), of conical form, but not spirally coiled. The shell is open at both ends, the anterior aperture being larger than the posterior, and the latter being sometimes simple, sometimes crenulated or fissured. The concave side of the tube corresponds with the dorsal side of the animal, and the ventral side is convex. No operculum is developed.

The *Dentaliidæ* are all marine, and live buried in sand or mud, with the wide anterior extremity of the shell downwards. The fossil forms begin at least as early as the Devonian, and some Ordovician and Silurian types have been recorded, though these are not free from doubt.



Fig. 734. — *Dentalium vulgare*, of the natural size, with the oral tentacles protruded from the anterior opening of the shell. (After Lacaze-Duthiers.)



Fig. 735. — *Dentalium Bouei*. Miocene. (After Deshayes.)

In the genus *Dentalium* (figs. 734 and 735) the tubular shell is smooth, or longitudinally striated, or annulated; the anterior aperture is simple and is not contracted; and the posterior aperture is typically truncated and entire. *Entalis* is hardly separable from *Dentalium* proper, but there is a short slit at the posterior aperture on the ventral (convex) side

of the tube. The fossil species of *Dentalium* may be confounded with the tubes of Tubicolar Annelides, or a reverse mistake to this may be made. Species of *Dentalium* have been described from the Ordovician rocks of Russia by Eichwald, but the nature of these is not absolutely certain. Undoubted forms of the genus appear in the Devonian rocks, and a number of Carboniferous species are known. In the Secondary and Tertiary rocks the genus is well represented, the later forms being usually more ornate as regards the characters of the surface than are the older types.

In the genus *Siphonodentalium* (*Gadus*) the tubular shell may or may not be contracted towards its anterior extremity, but is always attenuated behind ; and the posterior aperture is incised or lobulated. The surface is smooth or finely striated. The genus ranges from the Cretaceous rocks to the present day. Lastly, in the Recent and late Tertiary genus *Cadulus*, the tube is swollen in its middle, and both its apertures are entire, the hinder one being crenulated.

CHAPTER XLI.

CLASS V. CEPHALOPODA.

THE members of the class *Cephalopoda* are *bilaterally symmetrical Molluscs, with a large head, and having the body enclosed in a muscular mantle. The fore-part of the foot is split up into eight or more muscular processes or "arms," which surround the mouth; while the epipodia are well developed, and give rise, by apposition or fusion, to a muscular tube ("funnel") through which the effete water of respiration is expelled. One or two pairs of gills are contained within the pallial sac, and the sexes are always distinct.*

The *Cephalopoda*, comprising the Cuttle-fishes, Pearly Nautilus, &c., constitute the most highly organised of the classes of the *Mollusca*. They are all marine and carnivorous, and are possessed of considerable locomotive powers. At the bottom of the sea they can walk about, head downwards, by means of the arms which surround the mouth, and which are usually provided with numerous suckers or "acetabula." They are also enabled to swim, partly by means of lateral expansions of the integument or fins (not always present), and partly by means of the forcible expulsion of water through the tubular "funnel," the reaction of which causes the animal to move in the opposite direction.

The body in the *Cephalopoda* is bilaterally symmetrical, the cephalic region being conspicuously marked out, and being separated from the visceral region, which is enclosed in the mantle (fig. 736). The head bears a pair of large globular eyes, and has the mouth placed in the centre of its anterior surface. The mouth is surrounded by a circle of long muscular processes or "arms," formed by the splitting up of the margins of the foot. In the Cuttle-fishes there are always either eight or ten "arms," and these are provided with muscular suckers, which can be used in prehension. In the Pearly Nautilus, on the other hand, the arms are numerous, and are not furnished with suckers. The lateral margins of the foot ("epipodia") are, again, either placed in

apposition (*Nautilus*) or are actually united (Cuttle-fishes), in such a manner as to form a muscular tube, known as the "funnel." The funnel (fig. 736, *f*) is placed on the lower surface of the body, with its anterior extremity projecting beyond the mantle, while it opens behind into the pallial chamber. It serves for the elimination of the water which has been used in respiration, and the out-going currents also carry away with them the excretions of the kidneys and of the ink-sac, together with the fæces. By the contractions of the mantle, the water contained in the pallial sac can also be driven through the funnel in a succession of jets, driving the animal backwards through the water.

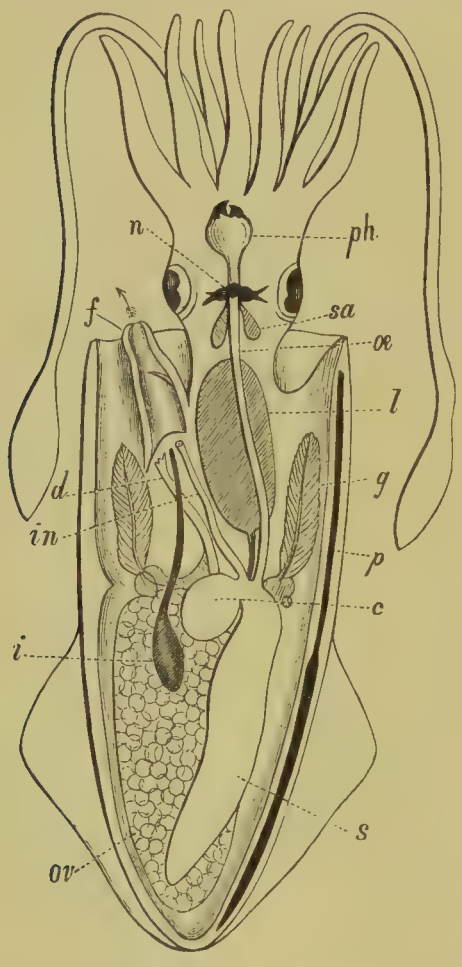


Fig. 736.—Diagram of the structure of a Cuttle-fish. *ph*, Pharynx, with the horny mandibles; *sa*, Salivary glands; *œ*, Œsophagus; *s*, Stomach; *c*, Gastric cæcum; *in*, Intestine; *l*, Liver; *n*, Œsophageal nerve-collar; *g*, One of the gills, with the branchial heart at its base; *i*, Ink-bag, its duct opening along with the intestine and generative duct at the base of the funnel; *ov*, Ovary; *d*, Oviduct (the nidamental and accessory glands are omitted); *f*, Funnel, *p*, Pen, lying in the mantle dorsally.

The mouth in the Cephalopods conducts into a powerful buccal cavity or pharynx (fig. 736, *ph*) containing two powerful mandibles, working vertically, resembling the beak of a parrot in shape, and either horny (as in the Cuttle-fishes), or partially calcified (as in *Nautilus*). There is also a toothed tongue or "radula." The intestine is short, and the anal opening is placed at the base of the funnel. The Cuttle-fishes possess a special glandular organ, the "ink-bag" (fig. 736, *i*), which secretes an inky fluid, which the animal can discharge into the water, so as to facilitate its escape when menaced or pursued. The duct of the ink-sac opens, along with the intestine, at the base of the funnel; but in the Pearly Nautilus and its extinct allies the ink-gland is entirely absent.

A well-developed heart is present in the Cephalopods, and the

respiratory organs are in the form of plume-like gills placed symmetrically on the sides of the body within the pallial sac. The Cuttle-fishes (Dibranchiate Cephalopods) have two gills, one on each side, while the Pearly Nautilus and its allies (Tetrabranchiate Cephalopods) have four gills, two on each side. The currents of water needed in respiration are maintained by the alternate contractions and expansions of the muscular walls of the mantle-sac. In each expansion the water finds its way into the pallial chamber by the opening between the rim of the mantle and the neck; and in each contraction it is expelled through the tube of the funnel, which is so constructed as to allow of the egress but to prevent the ingress of the water.

The nervous system of the *Cephalopoda* is highly developed, and its central masses form an œsophageal nerve-collar, which is protected by a cartilaginous plate.

The sexes are in different individuals, and the males and females are commonly more or less unlike externally, the former often having one of the arms specially modified to serve as an intromittent organ. The ducts of the generative glands open at the base of the funnel, and each individual, besides the essential organs of reproduction (testis or ovary), generally possesses accessory glands. The most important of these accessory glands in the females are known as the "nidamental glands," and they secrete a viscid material which unites the eggs together.

The *shell* of the *Cephalopoda* is sometimes external, sometimes internal. The internal skeleton (fig. 737) is known as the "cuttle-bone," "sepiostaire," or "pen" (*gladius*), and may be either corneous or calcareous. In some cases it is rendered complex by the addition of a chambered portion or "phragmacone," which is to be regarded as a visceral skeleton or "splanchnoskeleton." In *Spirula* (fig. 737, *c*) the phragmacone is the sole internal skeleton, and is coiled into a spiral, the coils of which lie in one plane, and are near one another, but not in contact. It thus resembles the shell of the Pearly Nautilus, but it is *internal*, and differs, therefore, in this respect from the *external* shell of the latter, though it is so far external that the last chamber lodges part of the viscera. The only living Cephalopods which are provided with an external shell are the Paper Nautilus (*Argonauta*) and the species of Pearly Nautilus (*Nautilus*); but not only is the structure of the animal different in each of these, but the nature of the shell itself is entirely different. The shell of the Argonaut is involuted, but is not divided into chambers, and it is secreted by the webbed extremities of the two dorsal arms of the female. The arms are bent backwards, so as to allow the animal to live in the shell, but there is in reality no organic connection between the shell and the body of the animal. In fact,

the shell of the Argonaut, being confined to the female, and serving by its empty apex as a receptacle for the ova, may be looked upon as a "nidamental shell," or, as it is secreted by a modified portion of the foot, it may more properly be regarded as a "pedal shell." The shell of the Pearly Nautilus, on the other hand, is a true pallial shell, and is secreted by the body of the animal, to which it is organically connected. It is involuted, but it differs from the shell of the Argonaut in being divided into a series of chambers by shelly

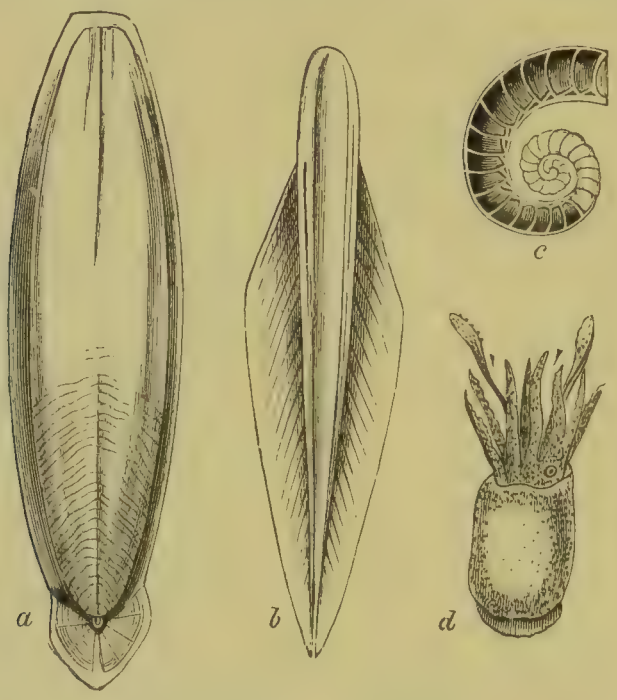


Fig. 737.—*a*, Internal skeleton of *Sepia ornata*; *b*, Pen of *Histioteuthis Bonelliana*; *c*, Shell ("phragmacone") of *Spirula fragilis*; *d*, Animal of *Spirula Peronii*.

partitions or septa, which are pierced by a tube or "siphuncle," the animal itself living in the last chamber only of the shell.

The *Cephalopoda* are divided into two extremely distinct and well-marked orders, termed the *Dibranchiata* and *Tetrabranchiata*, in accordance with the number of gills possessed by the animal. The former comprises all the true Cuttle-fishes; whilst the latter, though abundantly represented in past time, has no other living representatives than three or four species of the genus *Nautilus*.

As regards their *distribution in space*, the Cephalopods are exclusively inhabitants of the sea, and sometimes attain a great size. They live partly in the open sea and partly in shallow water close to shore, and are carnivorous in habit.

As regards their general *distribution in time*, the oldest forms of

the *Cephalopoda* (*Orthoceras* and *Cyrtoceras*) appear in the Upper Cambrian rocks. All the known Palæozoic representatives of the class belong to the order of the *Tetrabranchiata*, whereas the order of the *Dibranchiata* makes its first appearance in rocks of Triassic age. The Tetrabranchiates attain their maximum in the Secondary period, about six or seven thousand fossil forms being already known from strata of Palæozoic and Mesozoic age. On the other hand, but few Tertiary Tetrabranchiates have been recorded, and the order is represented at the present day by the single genus *Nautilus*. The order of the *Dibranchiata*, on the contrary, attains its maximum development at the present day.

CHAPTER XLII.

DIVISIONS OF THE CEPHALOPODA.

Order I. Tetrabranchiata.

The Tetrabranchiate Cephalopods are distinguished by the possession of *an external many-chambered shell, the last and largest chamber of which lodges the body of the animal. The chambers are separated by calcareous partitions or "septa," perforated by a membranous tube or "siphuncle." The head is furnished with numerous fleshy "tentacles," which are not provided with suckers; the branchiæ are four in number, two on each side of the body; the funnel does not form a complete tube; and there is no ink-bag.*

This order of the Cephalopods is represented at the present day by the single genus *Nautilus*, with four living species, and we may take the well-known Pearly Nautilus (*N. pompilius*) as the type of the division. The body of the Pearly Nautilus consists (fig. 738) of a posterior visceral mass and an anterior cephalic region, the whole being contained in the capacious outermost chamber (body-chamber) of the shell, from which the head can be protruded at will. The shell is rolled up into a flat spiral, and the position of the animal is such that the "funnel" (fig. 738, *f*) is turned towards the convex side of the shell, which is thus the ventral side, the concave side being dorsal. The visceral mass is included in the mantle, which is thin behind, but becomes thicker in front, being reflected on the dorsal side as a kind of collar over the convexity of the preceding whorl, which it invests with a black shelly deposit. The animal is attached to the shell by a double shell-muscle, while the posterior extremity gives off a membranous tube or "siphuncle," which pierces the successive septa centrally, and is continued backwards through the entire series of air-chambers.

The front portion of the "foot" surrounds the animal's mouth, and is furnished with a number of cylindrical, retractile "tentacles," which are not provided with suckers. Dorsally a portion of the

foot is thickened, and forms a fleshy fold or "hood" (fig. 738, *c*), which abuts against the preceding whorl of the shell. On the ventral side the median portion of the foot is converted into two muscular lobes, which are placed in apposition but are not fused with one another, thus forming the "funnel." As in all the Cephalopods, the funnel serves for the expulsion of the currents of water which have passed over the gills, as also for the escape of the undigested portions of the food and the generative products.

The mouth is placed in the centre of the head, and is armed with two horny mandibles, partially calcified towards their extremities, and shaped like the beak of a parrot, except that the inferior man-

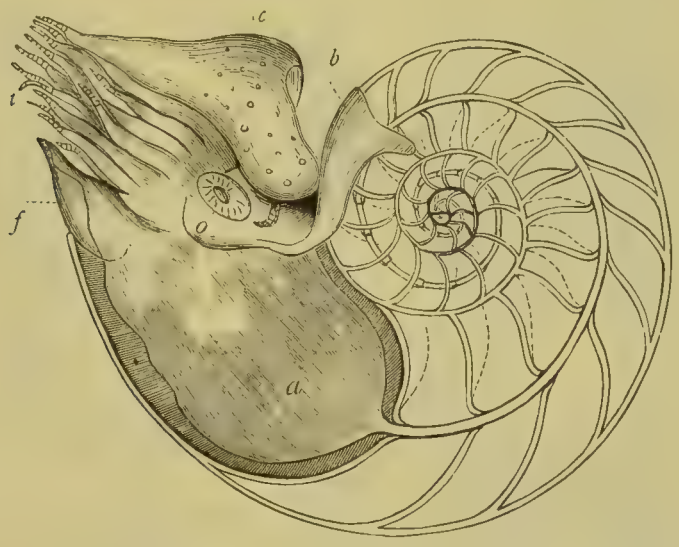


Fig. 738.—Pearly Nautilus (*Nautilus pompilius*). *a*, Mantle; *b*, Its dorsal fold; *c*, Hood; *o*, Eye; *t*, Tentacles; *f*, Funnel.

dible is the longest. A "radula" is present, and the intestine terminates at the base of the funnel. The heart is contained in a large viscero-pericardial sac (or "pericardium"), and consists of a ventricle, which receives four branchial veins; but there are no "branchial hearts." The branchiæ are contained within the mantle-cavity, and are four in number, two on each side. No ink-gland is developed. The sexes are distinct, and the reproductive organs of the female consist of an ovary, with two oviducts (the left rudimentary), and an accessory nidamental gland.

The only structures possessed by the Pearly Nautilus which are capable of preservation in the fossil condition are the mandibles and the shell, since the foot in this genus secretes no structure which can be compared with the "operculum" of the Gastropods. Leaving out of sight the "Aptychi" of the Ammonites, it is from fossil

beaks or shells that we derive our knowledge of the extinct Tetrabranchiates; and it is therefore necessary to study these parts in some detail, and with reference to the entire order.

In the living Pearly Nautilus the horny mandibles, which compose the "beak," are calcified towards their tips, the upper mandible more extensively so than the lower one. Similar beak-like jaws have been long known as occurring in the Secondary and Tertiary rocks, and they have been described under the name of *Rhyncholites*. The Jurassic and Cretaceous fossils included under the name of *Rhynchoteuthis* (fig. 739) are very similar to *Rhyncholites*, and are doubtless the calcified mandibles of some species of *Nautilus*, or of

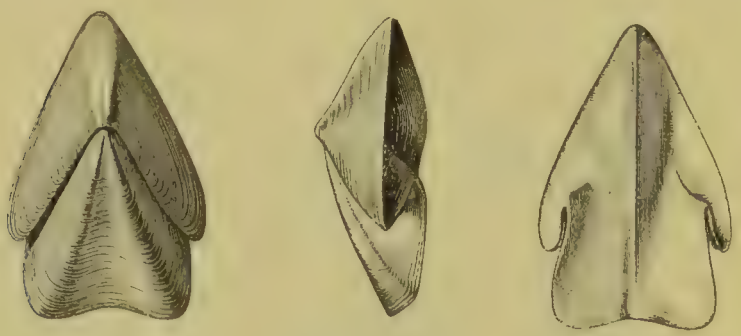


Fig. 739.—*Rhynchoteuthis Astierianus.* Lower Greensand (Cretaceous).

some allied type. In the Palæozoic rocks, in which the *Nautiloidea* are abundantly represented, the fossil beaks, except for a Carboniferous "Rhyncholite," are unknown.

The *shell* in all the Tetrabranchiates resembles that of the Nautilus in having a larger or smaller body-chamber, preceded by a chambered portion, which is divided into compartments by shelly partitions or "septa" (fig. 738). The chambers are usually spoken of as the "air-chambers," on the belief that they are filled with some gas secreted by the animal itself, but some authorities take the view that they are naturally filled with water. In all the Tetrabranchiates the chambers are traversed throughout by an originally membranous tube or "siphuncle," which is connected with the hinder end of the visceral sac.

In the Pearly Nautilus, as before pointed out, the animal is so related to its shell that the "funnel" is turned towards the convex side of the latter, the aperture of the shell showing a corresponding sinuation on that side. Hence, in the living Pearly Nautilus the convex side of the shell is ventral, and the shell is "exogastric." In various fossil Nautiloids, however, it can be shown that the shell-aperture is excavated on the inner or concave side, at which point we must suppose the "funnel" to have been placed. In such

"endogastric" types the concave side of the shell is the ventral side, the dorsal side being convex. In a great many fossil forms, however, there is no clear evidence as to the position of the animal in relation to its shell; and in such cases, as in the Ammonites, it is advisable to employ the terms "external" and "internal" for the convex and concave sides of the shell, since we do not know which side is "dorsal" or "ventral."

The shell of the Tetrabranchiates may be regarded as essentially a more or less elongated cone, the pointed end of which is parti-

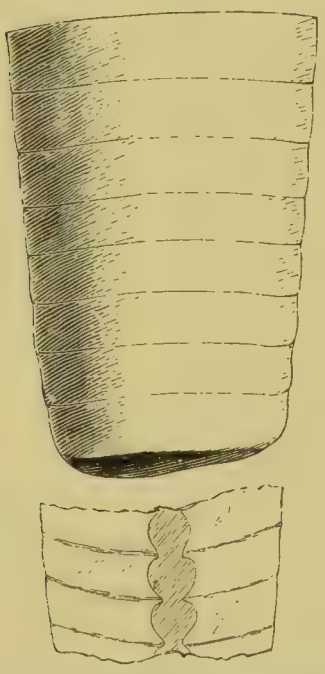


Fig. 740.—Fragment of *Actinoceras crebriseptum*—Cincinnati Group, North America, of the natural size. The lower figure is a section showing the air-chambers, and the form and position of the siphuncle. (After Billings.)

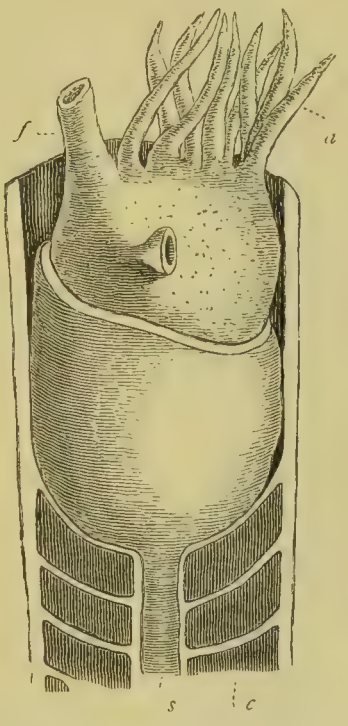


Fig. 741.—Restoration of *Orthoceras*, the shell being supposed to be divided vertically, and only its upper part being shown. *a*, Arms; *f*, Muscular tube ("funnel") by which water is expelled from the mantle-chamber; *c*, Air-chambers; *s*, Siphuncle.

tioned off into air-chambers, while the body-chamber is situated at the wide end (figs. 740 and 741). In some cases, as in *Orthoceras* and *Baculites*, the shell retains permanently its primitive form as a straight cone. In other cases the originally straight cone may be slightly bent (*Cyrtoceras*); twisted into a hook (*Hamites*); doubled on itself (*Ptychoceras*); or coiled into an open spiral, the turns of which may lie in one plane (*Gyroceras*) or may pass obliquely round an imaginary axis (*Helicoceras*). Very generally the volutions of the

shell are in contact with one another, in which case the coils may lie in one plane (*Nautilus*, *Ammonites*, &c.), or they may pass obliquely round an axis (*Turrilites*). In the discoidal types (such as Nautilus and the Ammonites) the last volution may more or less completely conceal the preceding turns of the spiral. In other cases the earlier coils of the shell remain visible, and the shell becomes umbilicated.

The surface of the shell in the Tetrabranchiates may be nearly smooth, or may show nothing more than delicate lines of growth. In other cases the surface may be more or less conspicuously adorned with various kinds of sculpturing, which may have a direction corresponding with the long axis of the shell, or may be at right angles to this. Thin sections show that the shell is composed of two principal layers, of a different nature. The outer layer forms a thin porcellanous stratum, which is lined throughout by a thicker nacreous layer, which alone forms the septa between the air-chambers.

The "septa," or partitions between the successive air-chambers, vary greatly in number in different types of the Tetrabranchiates.

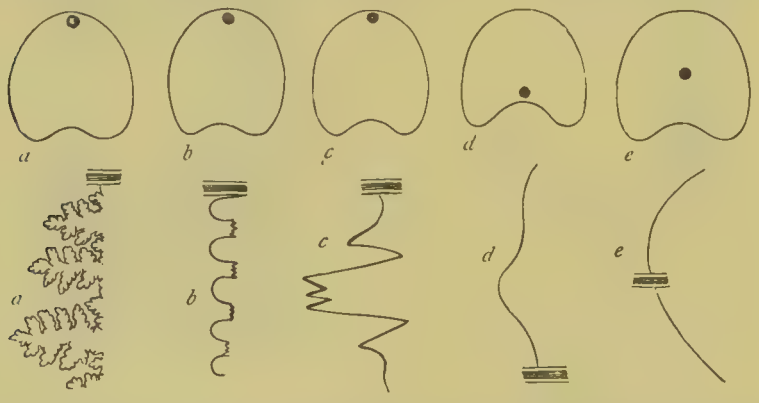


Fig. 742.—Diagram to illustrate the position of the siphuncle and the form of the septa in various Tetrabranchiate Cephalopods. The upper row of figures represents transverse sections of the shells, the lower row represents the edges of the septa. *a a*, *Ammonite* or *Baculite*; *b b*, *Ceratite*; *c c*, *Goniatite*; *d d*, *Clymenia*; *e e*, *Nautilus* or *Orthoceras*.

Whatever their number may be, they are usually placed in each individual at approximately uniform distances apart in each successive portion of the shell; but the last two or three septa are commonly closer to one another than the rest, probably in consequence of an impairment of the vitality of the animal with advancing age. Up to a certain period of the animal's life, new chambers are successively formed as the increasing size of the body necessitates the acquisition of more room, but the process by which the animal moves forwards prior to the development of a fresh septum is not perfectly understood. The edges of the septa, where they become

continuous with the shell-wall, are known as the "sutures," and the form of these necessarily varies with that of the septa themselves. In one great division of the Tetrabranchiates (viz., the *Nautiloidea*) the septa are simply curved or slightly lobed, and the "sutures" are more or less completely plain. In the other great division of the order (viz., the *Ammonoidea*) the septa are folded and complex, and the "sutures" are angulated, zigzag, lobed or foliaceous (fig. 742). The form of the "sutures" cannot be determined from the exterior, so long as the shell is preserved; but in fossil forms, in which the shell itself is commonly more or less extensively removed, the form of the sutures can be readily studied, and affords characters of high morphological value.

The "siphuncle" in the Tetrabranchiate Cephalopods has the form of a tube connected in front with the hinder end of the body, and continued backwards throughout the entire series of air-chambers. The precise function of the siphuncle is uncertain, but it probably serves to maintain the vitality of the shell. In the Pearly Nautilus the siphuncle is a membranous tube, the walls of which are to some extent strengthened by the deposition of calcareous granules. In some fossil Tetrabranchiates these calcareous deposits are so extensively developed that the wall of the siphuncle may become completely calcified. The proper sheath of the siphuncle, formed in this way, must, however, be carefully distinguished from certain other calcareous envelopes which may come to more or less completely enclose the siphuncular tube. Thus, in the Pearly Nautilus each septum is prolonged backwards at the point where it is perforated by the siphuncle as a short shelly tube — "neck" or "funnel" — which encloses the anterior portion of each segment of the siphuncle. In some Tetrabranchiates these "septal necks" do not merely form short collars round the siphuncle, but each is continued backwards from the septum in which it originates to the septum next behind (fig. 743, *si*); so that the proper siphuncle becomes enclosed in a complete secondary investment. In the majority of the Nautiloids the septal necks are directed, as in the Pearly Nautilus, *backwards* from each septum, and such forms are said to be "retrosiphonate." On the other hand, the majority of the



Fig. 743.—Partial section of the shell of *Aturia aturi*, showing the "septal necks" (*si*). From the Miocene deposits of Dax, Bordeaux.

Ammonoid Tetrabranchiates have the septal necks continued *forwards* from the producing septa, and are therefore said to be "prosiphonate." In many of the extinct types of the *Nautiloidea* the internal structure of the siphuncle is highly remarkable, the cavity of the tube often becoming contracted by organic deposits of secondary origin; but the structures in question will be more fully considered later on. Lastly, important distinctions are drawn in the Tetrabranchiates from the position of the siphuncle in relation to the shell. In the *Ammonoidea* the siphuncle is always marginal, and is mostly placed on the external side of the shell. In the *Nautiloidea*, on the other hand, the siphuncle may pierce the septa centrally (as in the Pearly Nautilus); or it may be subcentral; or in other cases it may be marginal, being then sometimes external, sometimes internal in position (fig. 742).

The development of the shell of the Pearly Nautilus is, unfortunately, unknown; but it has been shown that there are important distinctions in the form and structure of the initial chamber of the

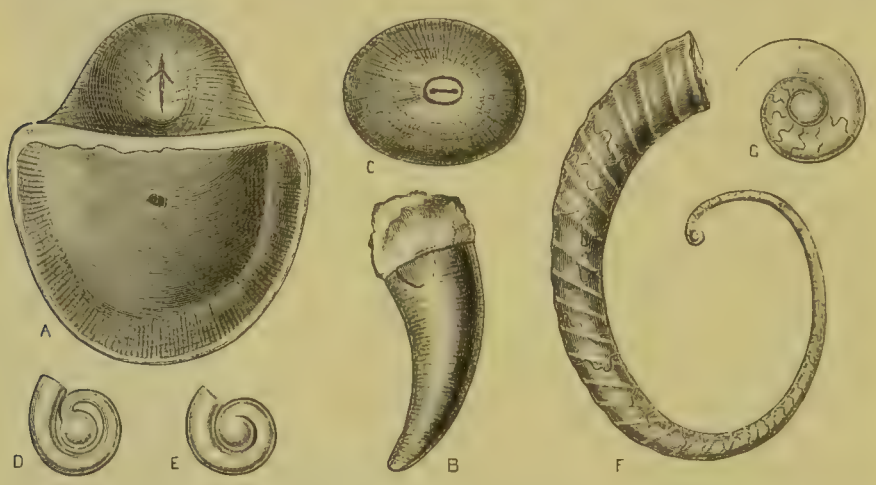


Fig. 744.—Development of Tetrabranchiate Cephalopods. A, The inner end of the shell of *Nautilus pompilius*, enlarged, showing the initial chamber and the cicatrix; B, *Cyrtoceras præposterum*—Silurian, showing the commencement of the shell; and (C) the initial chamber viewed from below, showing the cicatrix; D, Inner portion of the shell of *Goniatites bicanaliculatus*—Devonian, showing the inflated protoconch; E, First turn of the spire of *Goniatites sublamellosus*—Devonian; F, *Crioceras Studeri*—Cretaceous, enlarged, showing the protoconch; G, Protoconch and first turn of the spire of *Ammonites quadrisulcatus*—Cretaceous, enlarged. (After Barrande.)

shell in the two groups of the *Nautiloidea* and *Ammonoidea* respectively. In the Ammonoids the initial chamber of the shell (fig. 744, D—G) constitutes an inflated, spheroidal, oval, or pyriform sac, the so-called "protoconch" (or "ovisac"), which corresponds with the "nucleus" of the shell of the Gastropods, and is separated by a constriction from the first air-chamber. The siphuncle commences as a closed and dilated tube, which deeply indents the front wall of

the protoconch, but does not penetrate into the cavity of the latter. Munier-Chalmas has shown, further, that the cavity of the protoconch is traversed by a tubular organ or "prosiphon," which abuts against the front wall of the chamber, but does not communicate with the proper siphuncle, the place of which it is supposed to take in early life. In the *Nautiloidea*, on the other hand, the initial chamber of the shell (fig. 744, A, B, C) is a simple cone, which is not constricted off from the first air-chamber and is not inflated. The initial element of the siphuncle is a somewhat dilated cæcal tube, which indents the front wall of the initial chamber, but does not enter its cavity. The external surface of the initial chamber is usually marked by a network of transverse and longitudinal striæ, which mostly become obsolete in the adult shell. The hinder extremity of the initial chamber also exhibits an oval, rounded, or slit-like scar or cicatrix (fig. 744, A and C). The presence of this cicatrix would seem to show, as held by Hyatt, that the initial chamber of the Nautiloids does not correspond with the "protoconch" of the Ammonoids; and it seems not improbable that there existed in the former a deciduous protoconch, which is now represented only by a small vacuity in the centre of the shell (in the spirally-inrolled types). Hyatt, indeed, has described and figured the remains of this protoconch as occurring in certain species of *Orthoceras*. On this view, the initial chamber of the shell of the Nautiloids is really the first air-chamber, and the cicatrix in its posterior wall marks the point where this communicated with the caducous protoconch.

The order of the *Tetrabranchiata* may be divided into the two sub-orders of the *Nautiloidea* and *Ammonoidea*, typified respectively by the Nautili and the Ammonites. The *Ammonoidea* are regarded by Fischer as a separate order of the *Cephalopoda;* while the characters of the protoconch are regarded by some as affording ground for a reference of this division to the Dibranchiates rather than to the Tetrabranchiates.

Regarded as a whole, the Tetrabranchiate Cephalopods form a group which early attained its maximum, and is now almost extinct. The Palæozoic Tetrabranchiates are in the main of a decidedly simpler type than those which followed them. The largest number of generic types existed during the Mesozoic period, and the forms of this epoch are morphologically the most complex. With the close of the Secondary period disappeared almost all the characteristic Mesozoic types, and the order was left without any representative in the Tertiary rocks except the simple and ancient genus *Nautilus* and its immediate allies. As regards the two great sections of the order, the *Nautiloidea* are the most ancient, dating their existence from the Upper Cambrian. Not only is this the case, but they are pre-

eminently Palæozoic, only a few generic types surviving into the Secondary period. On the other hand, the *Ammonoidea* are pre-eminently Mesozoic in their range, being represented in the Palæozoic deposits earlier than the Carboniferous only by such comparatively simple types as *Clymenia* and *Goniatites*. With but limited and local exceptions, the *Ammonoidea* are not known to have survived into even the commencement of the Kainozoic period; and all the living *Tetrabranchiates* belong to the single genus *Nautilus*.

Sub-Order I. Nautiloidea.

In this division of the *Tetrabranchiata* the shell is straight or bent, or variously coiled, the aperture being simple or contracted, and the ventral side being commonly indicated by an emargination of the apertural edge. The sutures are simple, rarely undulated or denticulate; and the septa are concave towards the shell-aperture. The siphuncle is variable in position, and its cavity is often contracted by internal deposits. The "septal necks" are usually short, though sometimes long, and are generally directed backwards, the shell being "retrosiphonate." The initial chamber is conical, and has a cicatrix.

This sub-order includes the genus *Nautilus*, and a large number of wholly extinct types. The general characters of the shell have already been spoken of in dealing with the *Tetrabranchiata* as a whole; but there are a few special points which may be shortly noticed here.

The *aperture* of the body-chamber in the Nautiloids is variably shaped. In some cases, as in *Orthoceras*, the aperture is simple, as it is in the Pearly Nautilus; but the lateral margins of the aperture may be prolonged forwards, so that a sinus is produced on the convex and concave sides of the shell. The most marked and constant of these sinuses may be assumed to correspond with the funnel, and therefore to represent the ventral side of the animal; and, as previously pointed out, this is in *Nautilus* the convex side of the shell. While the aperture in many Nautiloids is simple, it becomes in other cases contracted by the bending inwards of the lateral prolongations of the mouth, so as to be converted into a dorsal and ventral opening connected by an intervening passage. In some cases the dorsal and ventral margins as well as the lateral ones are bent inwards, in which case the aperture (fig. 745) assumes a T-shaped



Fig. 745.—Aperture of the shell of *Gomphoceras Bohemicum*, reduced in size. (After Barrande.)

or key-hole-like character. According to the views of Barrande, the broad transverse part of the aperture represents in such cases the position of the head, while the rounded extremity of the vertical portion of the aperture corresponds with the funnel. It is clear, however, that with an aperture so contracted, the animal must have been incapable of protruding the head, as the living Pearly Nautilus can.

The dorsal and ventral aspects of the animal have no constant relation to the concave and convex sides of the shell among the *Nautiloidea*. In the Pearly Nautilus the convex side is the ventral one, but even within the limits of the same genus it is usual to meet with forms having the convex side ventral associated with others in which the concave side is ventral.

The *position of the siphuncle* is by no means constant among the Nautiloids, and bears no fixed relation to the aspects of the body of the animal, though it is commonly placed towards the ventral side. The siphuncle is upon the whole, however, most generally situated centrally or subcentrally, and when removed towards the margin it is usually external in the curved shells, though it may be internal. As regards its *structure* the siphuncle of the Nautiloids is, to begin with, a simple membranous tube, but it may become complex in process of growth. In many cases the cavity of the siphuncle becomes contracted by the formation in its interior of annular deposits of calcareous tissue (fig. 746, *or*), which were termed by Barrande "obstruction-rings"; and these may be so extensively developed as to completely obstruct the tube.

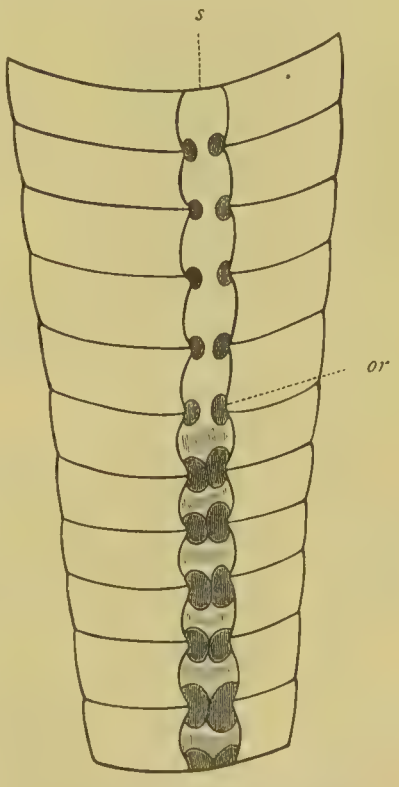


Fig. 746.—Vertical section of *Orthoceras angulatum*, Silurian, showing the siphuncle (*s*) contracted by the development of "obstruction-rings" (*or*) opposite the septa. (After Foord.)

The "*septal necks*" of the Nautiloids are almost always directed backwards, the shell thus being "retrosiphonate" (fig. 743). In the two genera *Nothoceras* and *Bathmoceras* alone are the septal necks turned forwards, so that the shell is "prosiphonate." In many forms, as in the existing Pearly Nautilus, the septal necks are short; but in other cases

they extend from septum to septum, and they may even fit into one another like so many funnels (as in the genus *Endoceras*).

Lastly, the "*sutures*," or the lines formed by the intersection of the septa with the surface of the shell, are simply curved, sigmoidally bent, or in some cases undulated. In a few cases short external and internal bendings of the suture ("lobes") may be developed, but these never constitute a conspicuous feature.

As regards their *distribution in time*, the earliest types of the *Nautiloidea* appear in the Upper Cambrian deposits, in which the genera *Orthoceras* and *Cyrtoceras* are represented. In the Ordovician rocks an enormous number of Nautiloids are known to occur, no less than four hundred and sixty-three species having been recorded by Barrande from rocks of this age in Bohemia alone. The maximum development of the group takes place, however, in the Silurian period, the Bohemian area having yielded to the researches of Barrande over a thousand species from deposits belonging to this system. In the later Palæozoic rocks the Nautiloids exhibit a progressive diminution in numbers, and only the genera *Nautilus* and *Orthoceras* survive the close of this epoch, the latter finally dying out in the Trias. The few known Tertiary types belong to *Nautilus* or to closely allied forms, and the sole existing representatives of the sub-order are four living species of *Nautilus*.

The sub-order *Nautiloidea* may be divided into the following families (see Foord's "Catalogue of the Fossil Cephalopoda in the British Museum"):—

Family 1. Orthoceratidæ.—In this family the shell is straight or slightly curved, the aperture is simple, and the siphuncle is usually slender and cylindrical. This family comprises the single genus *Orthoceras* (figs. 747, 748), in which the shell is in the form of a conical tube which is usually straight, but may be slightly curved. The aperture of the shell is not contracted, and the body-chamber is of large size. The septa are concave, usually horizontal, and generally far apart; and the siphuncle is usually slender and cylindrical, and may be central, subcentral, or excentric in position. The numerous species of *Orthoceras* are divided by Barrande into two principal sections—the Short-coned and Long-coned forms—according as the shell has the form of a short cone with a large apical angle, or of a prolonged cone with a small apical angle. The first of these groups is a very small one, and almost all the more common *Orthocerata* belong to the second section. Though the shell is typically straight, it may be gently curved throughout (as in *O. angulatum*); or it may be slightly bent towards the point of the cone, but otherwise straight (as in *O. unguis*). In the smaller forms, the initial chamber, with its cicatrix, is sometimes preserved.

The oldest known species of *Orthoceras* appears in the Upper

Cambrian (Upper Tremadoc beds of Wales), and very numerous forms of the genus have been recorded from the Ordovician rocks. The genus attains its maximum in the Silurian, more than five hundred species having been described by Barrande from rocks of this age in Bohemia. In the Devonian and Carboniferous rocks a great reduction in the number of species takes place; a few Permian



Fig. 747.—*a*, A broken specimen of *Orthoceras ornatum*, of the natural size, from the Silurian rocks of Gotland; *b*, Transverse section of the shell, showing the position of the siphuncle; *c*, Portion of the surface, enlarged. (After Foord.)

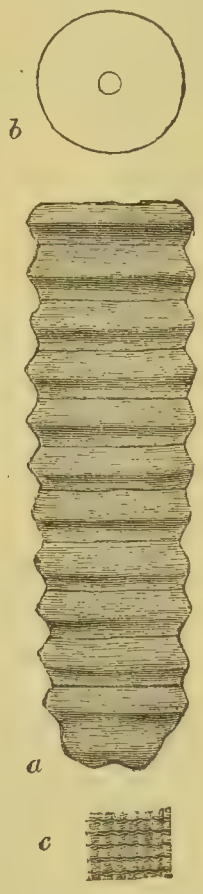


Fig. 748.—*a*, Cast of the shell of *Orthoceras Hisingeri*, from the Silurian rocks of Gotland, of the natural size; *b*, Transverse section of the shell, showing the siphuncle; *c*, Portion of the surface, enlarged. (After Foord.)

types are known; and the last representatives of the genus are found in the Alpine Trias.

Family 2. Endoceratidæ.—In this family the shell is straight or slightly curved; the siphuncle is marginal or sub-marginal, of large size; and the septal necks are invaginated so as to form a wide tube within which the siphuncle is contained.

The type-genus of this family is *Endoceras*, in which the shell is straight and resembles that of *Orthoceras* in form. The septal necks (fig. 749, *sp*) are prolonged backwards to such an extent that each becomes inserted into the mouth of the neck of the septum next behind, thus forming a complete and wide tube which encloses the siphuncle. This siphuncular tube is marginal or sub-marginal, and may attain a diameter of one-half of that of the shell. The siphuncular tube is provided internally with a series of funnel-shaped sheaths (fig. 749, *sh*), which are not very numerous, and occur at irregular intervals. These were termed by Hall "embryo-sheaths," upon the belief that they were connected with reproduction; but

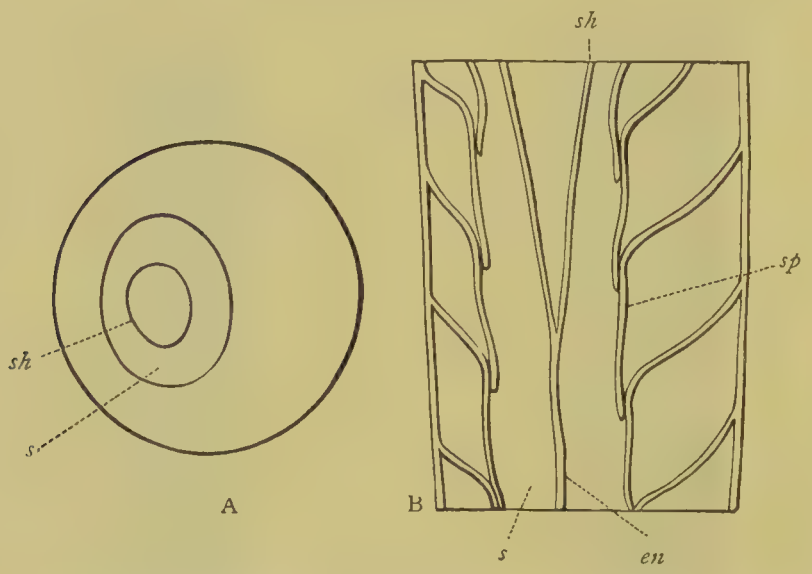


Fig. 749.—A, Transverse section of the shell of *Endoceras*; B, Vertical section of part of the shell of *Endoceras Wahlenbergi*, from the Ordovician rocks of Sweden (after Foord): *s*, Cavity of the siphuncle; *sp*, One of the "septal necks"; *sh*, One of the siphuncular sheaths; *en*, Endosiphon.

their true nature is not absolutely certain. In well-preserved examples, the great siphuncular space contains in its interior a cylindrical slender tube or "endosiphon" (fig. 749, B, *en*), which probably represents the calcified wall of the proper siphuncle. With the doubtful exception of one Silurian species (*E. ? Ommaneyi*) the genus *Endoceras* is confined to the Ordovician rocks. *Endoceras Wahlenbergi* (the *E. duplex* of many writers) is abundant in the Ordovician deposits of Scandinavia and Russia, and sometimes attains a length of six feet or more. Casts of the great siphuncular tube are not uncommon, and have the form of cylinders marked with oblique annulations.

In the genus *Piloceras* the shell is more or less broadly conical,

slightly curved, with a large marginal siphuncular tube, formed by the prolongation and conjunction of the septal necks, and provided internally with one or more funnel-shaped sheaths, which are united at the top with its margin. "These sheaths apparently communicated with one another by means of the endosiphon, which passed from the initial chamber into the siphuncular cavity by means of a large foramen, situated on the inner curvature of the siphuncle a little above the apical point" (Foord). The species of *Piloceras* are confined to the summit of the Cambrian and the base of the Ordovician deposits (the Durness Limestone of Britain and the Calciferous formation and Quebec group of North America).

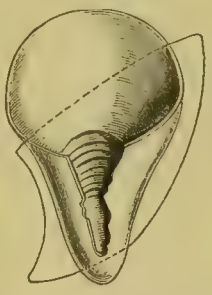


Fig. 750.—*Cyrtocerina typica*, Ordovician (Quebec Group), Canada. (After Billings.)

The genus *Cyrtocerina* (fig. 750), of the Lower Ordovician rocks (Quebec Group) of Canada, is perhaps allied to *Piloceras*. In this type, the shell is broadly conical and is curved, and there exists on the concave side of the shell a wide marginal siphuncular tube.

Family 3. Actinoceratidæ.—In this family the shell is straight or slightly curved, and the siphuncle is of large size and is composed

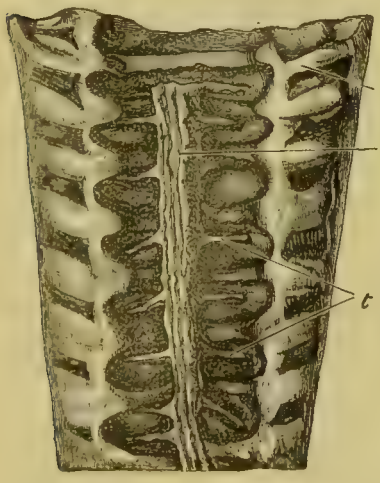


Fig. 751.—Weathered fragment of *Actinoceras Bigsbyi*, of the natural size, from the Ordovician rocks of Lake Huron. *s*, Septa; *en*, Endosiphon, with some of its tubuli (*t*). (After Foord.)

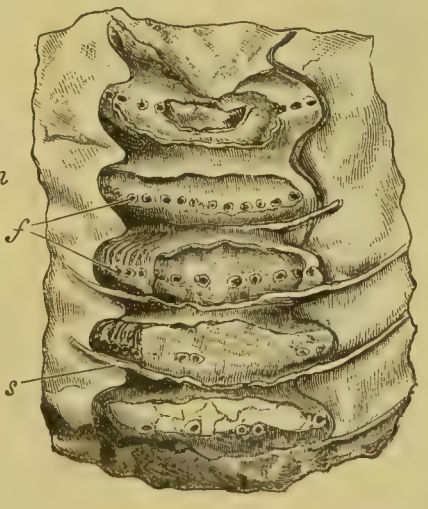


Fig. 752.—Fragment of *Actinoceras Bigsbyi*, from the Ordovician rocks of Kentucky, of the natural size. *s*, One of the septa; *f*, Foramina in the siphuncle by which the tubuli thrown out by the endosiphon may have communicated with the septal chambers. (After Foord.)

of nummuloid segments or discs, its internal cavity being more or less extensively contracted by the development of "obstruction-rings."

The type of this family is the genus *Actinoceras* (figs. 751 and 752), in which the shell is elongate-conical, and often of large size. The siphuncle is very large, its diameter sometimes equalling half that of the shell; and it is greatly inflated between the septa, so that it comes to present a series of segments of a compressed-globular form. In the centre of the main siphuncular tube is a cylindrical "endosiphon" (fig. 751, *en*), and the space between this and the wall of the former is largely occupied by secondary calcareous deposits ("obstruction-rings") developed at the "necks" of the septa. "The endosiphon is provided with a distinct wall, and gives off at regular intervals between the septa a number of radiating canals or tubuli (fig. 751, *t*), which apparently penetrate the shelly covering or wall of the siphuncle" (Foord). The foramina by which these tubuli open externally form a ring round each segment of the siphuncle (fig. 752, *f*), and they may perhaps have served to transmit blood-vessels to the lining-membrane of the air-chambers. The genus *Actinoceras* ranges from the base of the Ordovician (Upper Cambrian?) to the Carboniferous limestone, the *A. giganteum* of this latter formation attaining a length of from four to six feet.

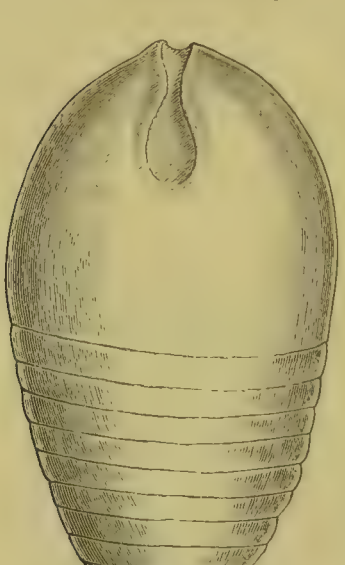


Fig. 753.—*Gomphoceras Bohemicum*, Silurian, Bohemia. (After Barrande.)

Allied to *Actinoceras* are the genera *Discosorus*, *Huronia*, and *Sactoceras*, all of which are confined to the Silurian rocks.

Family 4. Gomphoceratidæ. — In this family the shell may be approximately straight or more or less extensively curved, and the aperture of the shell is contracted and T-shaped (fig. 745). The principal genus in this family is *Gomphoceras*, with which may be included the forms usually spoken of as *Phragmoceras*.

In the most typical forms of *Gomphoceras* (fig. 753) the shell is approximately straight, or is very slightly curved, and the ventral side is always more convex than the dorsal, the shell being thus "exogastric"; while the siphuncle is situated towards the convex or ventral aspect. The aperture of the shell (fig. 745) is T-shaped; and the transverse orifice, corresponding with the head, may be widely expanded or may be contracted in the middle. The siphuncle is commonly subcentral, the septa are simply curved, and the body-chamber is of large size. The name of *Phragmoceras* has been given to forms of *Gomphoceras* in

which the shell (fig. 754) is more or less curved, the dorsal side being convex and the ventral side concave, and the shell being thus "endogastric;" while the siphuncle runs on the ventral aspect. The form of the aperture is not affected by this reversal of the curvature of the shell, except that the smaller opening of the T-shaped mouth, corresponding with the funnel of the animal, is now turned towards the concave side of the shell.

The genus *Gomphoceras* (including *Phragmoceras*) has been stated to range from the Ordovician to the Carboniferous; but, according to Foord, the pre-Silurian and post-Silurian types referred to this genus are of doubtful affinities, or are certainly known to be refer-

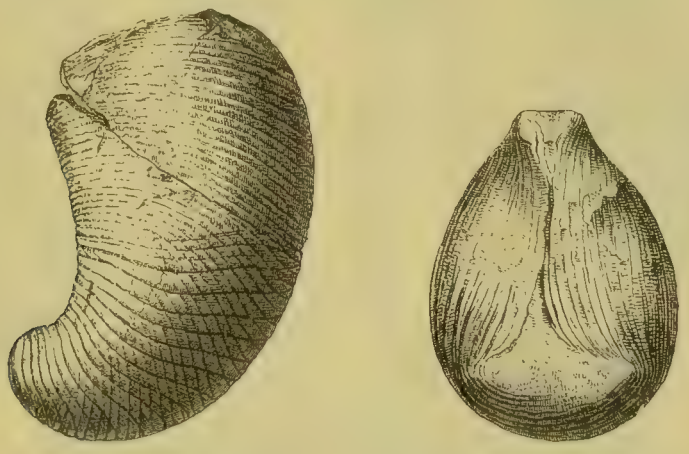


Fig. 754.—*Gomphoceras* (*Phragmoceras*) *ventricosum*. Silurian. The right-hand figure shows the form of the aperture.

able to other genera. The genus is therefore restricted, so far as clearly ascertained, to the Silurian period.

Family 5. Ascoceratidæ.—In this family the shell, when fully grown, is sac-like and truncated below, the body-chamber occupying most of the ventral side, while the last few septa are specially modified. The aperture may be simple or contracted.

The type of this family is the genus *Ascoceras* (fig. 755), which is defined by Foord as follows: "The shell is of a sac-like form, essentially straight, but always more convex on the ventral than on the dorsal side. The apex is unknown, the shell being always truncated. The transverse section may be elliptical or circular. The body-chamber occupies nearly the whole length of the shell on the ventral side, and contracts into a neck-like prolongation towards the aperture, which is simple. The last few septa are abnormal; they have the usual shape and position on the ventral side of the shell, but on the dorsal side they coalesce, and sweeping upwards in a sigmoid curve (as seen in section, fig. 755, *a*) form a series of

vaulted chambers, convex towards the aperture, and encroaching considerably upon the body-chamber. This extraordinary conformation of the septa on the dorsal side was doubtless caused by the shrinking of the animal in its shell on that side; whereby a cavity was created between the shell-wall and the mollusc, and then partitioned off in the manner above described. The short siphuncle is submarginal and near the ventral or convex border of the shell; it diminishes rapidly in size towards the body-chamber. The test is



Fig. 755.—*Ascoceras Bohemicum*, Silurian, Bohemia. *a*, Longitudinal section, showing the septa (*s s*) and siphuncle (*si*); *b*, Ventral aspect of the cast of the shell, showing the reduction in size of the body-chamber caused by the encroachment of the septa; *c*, Dorsal view of the same specimen; *d*, Body-chamber, without the air-chambers; *e*, Transverse section taken in the centre of the fossil; *f*, Truncated posterior extremity, showing the position of the siphuncle (*si*); *g*, Anterior extremity, showing the simple form of the aperture (*ap*). The letters *v* and *d'* indicate the ventral and dorsal sides respectively. (After Barrande.)

relatively thick considering the size of the shell; its ornaments may consist of transverse lines or of annulations."

By the researches of Lindström it has recently been proved that *Ascoceras* begins in the form of an *Orthoceras*, having a cylindrical shell, with remote, simply curved septa, and a slender tubular siphuncle, and that the sac-like shell above described is only the final portion of the structure. When the organism has attained its full growth, and has formed the inflated *Ascoceras*-shell, the older, Orthoceratoid portion becomes decollated or cast off. It is, therefore, a matter of extreme rarity to find a complete specimen of *Ascoceras*, exhibiting both the older and later portions of the shell.

The species of *Ascoceras* are found in the Silurian rocks in Europe, and in the Ordovician rocks in North America. The Silurian genus *Glossoceras* resembles *Ascoceras* in general structure, but the aperture is contracted and lobed. The name of *Aphragmites*, again, is given to forms in which the peculiar arched septa at the side of the body-chamber are absent, the shell otherwise resembling *Ascoceras*.

Family 6. Poterioceratidæ.—The principal genus included in this family is *Poterioceras*, in which the shell is fusiform in shape, inflated in the central portion of its length, contracted towards the aperture, and very slender in its apical portion. The siphuncle is subcentral or marginal, and is inflated between the septa. The shell has a general resemblance to *Gomphoceras*, but the aperture is simple. The species of *Poterioceras* range from the Ordovician to the Carboniferous.

Family 7. Cyrtoceratidæ.—This family includes only the genus *Cyrtoceras*, in which the shell (fig. 756) is more or less curved, but

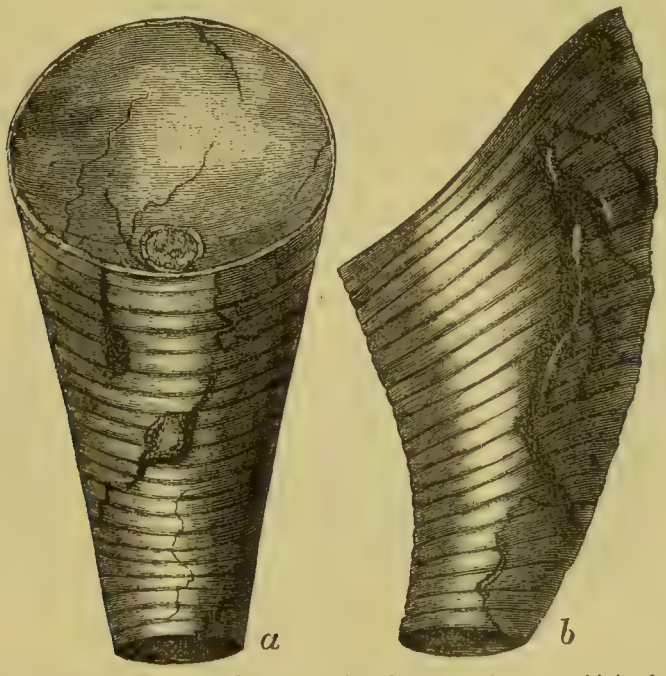


Fig. 756.—*Cyrtoceras obliquum*, Middle Devonian, Germany, about two-thirds of the natural size. *a*, Front view; *b*, Side view. (After Foord.)

does not form a complete volution, and the body-chamber is of large size. The septa are simple, concave forwards, and the siphuncle may be internal, external, or subcentral in position, and may be cylindrical or beaded. The shell is conical, or sometimes subcylindrical in form, some species being of the "brevicone" type, while others are "longicone." The genus *Cyrtoceras* ranges from

the Cambrian to the Carboniferous, and attains its maximum in the Silurian period, more than three hundred species having been described by Barrande from the Silurian deposits of Bohemia alone.

Family 8. Lituitidæ.—The shell (fig. 757) in this family has its earlier portion coiled into a flat spiral, while the later portion, including the whole or the greater part of the body-chamber, is produced in a straight line. The volutions of the spiral part of the shell may or may not be in contact, and the siphuncle is subcentral or internal. The septa are simple and concave, and the surface is transversely striated or ribbed.



Fig. 757.—*Lituites cornu-arietis.* Ordovician.

In *Lituites* itself the uncoiled portion of the shell is very long, and the aperture is contracted, with a deep ventral sinus. The genus is found in the Ordovician and Silurian rocks. The Silurian genus *Ophidioceras* resembles *Lituites* in most respects, but the disjunct portion of the shell is short, and contains a portion only of the body-chamber. Lastly, in the genus *Discoceras*, also from the Silurian, the terminal and produced portion of the shell is short, but the aperture differs from that of *Ophidioceras* in being simple.

Family 9. Trochoceratidæ.—In this family the shell is rolled up into a spiral, the coils of which do not lie in a single plane. In *Trochoceras* the shell is unsymmetrically coiled, and the last volution may be partially disjunct. The septa are concave, and the siphuncle is usually placed between the centre and the convex external margin; while the aperture is simple. The genus ranges from the Ordovician to the Devonian, but the great majority of the species are Silurian. The Silurian *Adelphoceras* differs from *Trochoceras* in having a contracted aperture to the shell.

Family 10. Nautilidæ.—In this family the shell is spirally inrolled, the coils lying in one plane, and the aperture being simple or contracted. Of the numerous generic types included in this family, the following are the most important:—

In the Ordovician genus *Trocholites* the shell is discoidal and umbilicated, and the septa are concave, the suture-lines being simple or feebly lobed. The siphuncle is sub-marginal, placed towards the internal side, and the septal "necks" are long, and reach from one septum to the next.

In *Gyroceras* (fig. 758) the shell is in the form of a flat spiral, the coils of which are not in contact with one another. The aperture is simple, with a ventral and dorsal sinus; the sutures are simple;

the siphuncle is variable in position, but is usually placed between the centre and the convex side; and the surface is commonly adorned with tubercles or ribs. The genus ranges from the Silurian to the Carboniferous.



Fig. 758.—*Gyroceras ornatum.* Devonian.

In *Hercoceras* the shell is discoidal, with contiguous whorls and a wide umbilicus. The aperture is contracted; the sutures are simple; the siphuncle is submarginal and external; and the surface is adorned with transverse striæ or a row of projecting tubercles. The two known species are Silurian.

In the genus *Nautilus* itself (fig. 759) the shell is involute or discoidal, consisting of a few whorls coiled into a flat spiral, the volutions being in contact, and the last turn of the shell commonly more or less concealing the previous ones. In the young condition of the shell a central vacuity exists behind the conical initial chamber; but in the typical forms of the genus this becomes ultimately filled up by a secondary deposit of shell, or becomes concealed by the later volutions. The body-chamber is capacious, and the aperture is simple and has a ventral sinus. The



Fig. 759.—*Nautilus Danicus.* Upper Cretaceous.

septa are concave forwards, and the suture-lines are simple or may show a slight ventral or dorsal "lobe." The siphuncle is subcentral in position, or may be placed between the centre and either the ventral or the dorsal margin, and it is never contracted by internal deposits; while the septal "necks" are always short. The surface may be quite smooth (*Lævigati*), or adorned with transverse striæ (*Striati*), or with markedly distinct ribs (*Radiati*).

The genus *Nautilus* has been split up into a number of minor

groups, to some of which a generic value is now usually attached. Using the name in the wide sense in which it has been commonly employed, the genus may be said to range from the Ordovician to the present day; but the older types are almost certainly not congeneric with those of later periods.

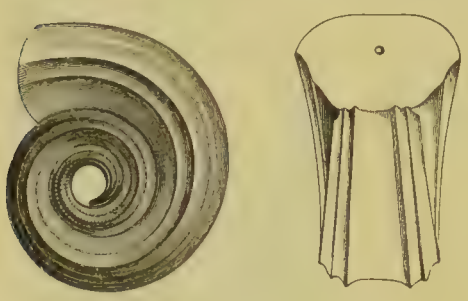


Fig. 760.—*Nautilus* (*Vestinautilus*) *Koninckii*. Carboniferous.

The name of *Discites* is given to forms generally included in the comprehensive genus *Nautilus*, in which the shell is widely umbilicated, with a persistent central vacuity; the volutions being four-sided, and the septa showing a deep ventral lobe. The forms of this type are Carboniferous. *Temnocheilus* (Devonian to Trias) and *Trematodiscus* (Carboniferous) likewise include widely umbilicated Nautili, in which the centre is perforated. A similar condition of parts exists in *Vestinautilus* (fig. 760), but in this type the whorls are trapezoidal in section and are very wide towards the aperture. The outer side of the shell is strongly keeled with lateral longitudinal ribs separated by a dorsal furrow. The genus is confined to the Carboniferous rocks.



Fig. 761. — *Bactrites elegans*, Devonian, Germany, of the natural size. (After Sandberger —copied from Zittel.)

Lastly, in *Aturia* the shell is involute and destitute of an umbilicus; and the sutures are strongly bent in a zigzag manner, with a deep lateral "lobe." The siphuncle is marginal and is placed on the internal side of the shell, the septal "necks" (fig. 743, *si*) being very long and being invaginated in such a manner as to form a complete siphuncular investment. The known species of *Aturia* are found in the Eocene and Miocene deposits.

Family 11. Bactritidæ. — This family includes only the genus *Bactrites* (fig. 761), in which the shell is straight and conical, with a circular or elliptical section, resembling that of *Orthoceras* in form. The siphuncle is delicate and marginal in position; and the septal necks are long and funnel-shaped. The sutures are undulated, with a backwardly-directed sinus corresponding with the siphuncle. Owing to the characters of the suture-lines, the genus *Bactrites* has been regarded as related to the

Goniatites, and as representing an ancient type of the Ammonoids, but it is now generally placed among the Nautiloids. The species of the genus are Silurian and Devonian.

Prosiphonate Nautiloids.

All the groups of the Nautiloids which have been previously considered are "retrosiphonate," having the septal necks directed backwards. On the other hand, the genera *Nothoceras* and *Bathmoceras* are "prosiphonate," the septal necks being directed towards the aperture of the shell. The genus *Bathmoceras* is Ordovician, and is characterised by the possession of a straight cylindro-conical shell, the septate portion of which is always truncated. The aperture is simple, and the siphuncle is marginal, and is ensheathed by numerous short invaginated funnels derived from the closely-set septa. In the Silurian genus *Nothoceras* the shell is nautiloid and widely umbilicated; the sutures are simple and concave; the siphuncle is ventral in position; and the septal necks are short and are directed forwards.

CHAPTER XLIII.

TETRABRANCHIATE CEPHALOPODS—continued.

Sub-Order II. Ammonoidea.

In this division of the Tetrabranchiate Cephalopods, the shell is usually rolled up into a spiral disc, but may be turreted, straight, hook-like, &c. The aperture may be simple, or may be furnished with lateral and ventral processes. The siphuncle is slender, cylindrical, marginal in position, and never contracted internally by shelly deposits. The septal "necks" are generally directed forwards, though in some forms (*e.g.*, *Goniatitidæ*) the reverse of this obtains. The septa are more or less folded or lobed, and the sutures are waved, angulated, or bent into "lobes" and "saddles." The structures known as the "Aptychus" and "Anaptychus" are commonly present. Lastly, the shell commences with a globular or inflated "protoconch," which is more or less clearly constricted off from the first septal chamber (fig. 744, D—G).

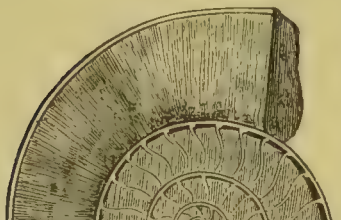


Fig. 762. — Section of *Arietites obtusus*, from the Lias, showing the long body-chamber.

The general structure of the shell and its mode of development have been already treated of (see p. 829 and p. 832); but there are some special features in the shell of the *Ammonoidea*, as compared with that of the *Nautiloidea*, which require consideration here.

The *body-chamber* of the *Ammonoidea* is of variable size, but in a number of forms it is remarkable for its great length as compared with its diameter (fig. 762), this implying that the body of the animal was very long and narrow. In some cases, indeed, the body-chamber may occupy an entire volution of the shell, or even a volution and a half.

The *aperture* of the shell in the Ammonoids is commonly furnished with lateral extensions or "ears," while its ventral or external side may be prolonged into a long pointed process or lobe. In this way a kind of cowl is sometimes formed above the aperture, and the width of the opening may be considerably contracted by the inward bending of these lobes (fig. 763). In the *Goniatitidæ* and *Clymeniidæ* the aperture resembles that of *Nautilus* in being simple, with a ventral sinus. In many cases the shell exhibits at intervals transverse ridges or contractions ("varices"), which represent the periodically formed mouths of the shell.

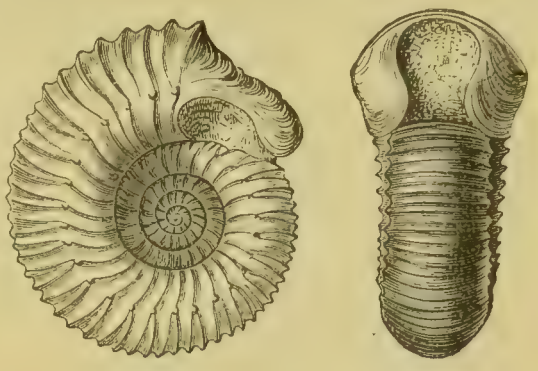


Fig. 763.—*Stephanoceras Brackenridgii*, viewed laterally and in front, showing the extensions of the margin of the aperture. Jurassic.

The *ventral* and *dorsal* sides of the shell of the Ammonoids cannot be always determined with certainty. There are, however, strong grounds for considering the external or convex side of the bent shells to be ventral, while the concave or internal side is dorsal.

The siphuncle in the Ammonoids is always cylindrical, and is never furnished internally with secondary calcareous structures resembling the "obstruction-rings" of many Nautiloids. Usually the sheath of the siphuncle is calcified, so that a continuous shelly tube is produced. The siphuncle commences by an inflated portion (fig. 764, *a*), which indents the protoconch (*pr*) on one side; and it is, to begin with, either internal or central in position. In the majority of the Ammonoids the siphuncle ultimately comes to be placed on the external margin of the shell (fig. 764, *si*), but in the *Clymeniidæ* it remains internal. The septal "necks" of the Ammonoids are variable in their development, as also in position.

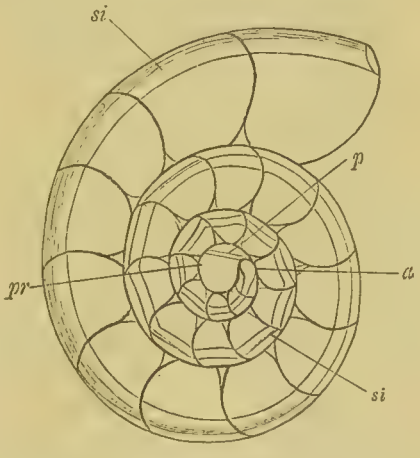


Fig. 764.—Section of *Ammonites* (*Cosmoceras*) *Parkinsoni*, in the mesial plane, showing the "prosiphon" (*p*), the siphuncle (*si*) with its dilated commencement (*a*), and the protoconch (*pr*). (After Munier-Chalmas.)

In most cases the shell is "prosiphonate," the septal necks being directed forwards, and being at the same time usually feebly developed. In the *Clymeniidæ* and *Goniatitidæ* the shell is "retrosiphonate," the septal necks being directed backwards; and in the former family these structures are so largely developed that they extend from one septum to the next behind.

The septa of the first-formed chambers of the shell of the Ammonoids are simply curved, or may be more or less bent, whereas in the adult portion of the shell they are always undulated or folded, the degree to which this takes place varying in different types. In the more specialised forms of the Ammonoids the septa "are nearly flat in the middle, and folded round the edge (like a shirt-frill) where they abut against the outer shell-wall" (Woodward). The result of this is that the "sutures," or edges of the septa, appear on the sur-

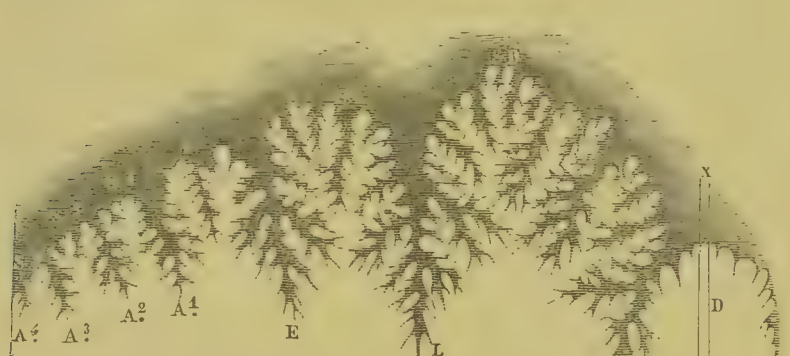


Fig. 765.—One-half of the suture of *Ammonites* (*Amaltheus*) *Truellei*; D, Siphonal or ventral lobe, traversed by the siphuncle (*x*); L, Superior-lateral lobe; E, Inferior-lateral lobe; A^1, A^2, A^3, A^4, Auxiliary lobes; S D, External saddle; S L, Lateral saddle; S^1, S^2, S^3, S^4, Auxiliary saddles.

face of the shell in the form of angulated, lobed, or foliaceous lines (fig. 765).

The angulated or digitated portions of the suture which are directed backwards, away from the mouth of the shell, are called the "*lobes*." The elevations between the "lobes," which point towards the aperture of the shell, are called the "*saddles*." These parts (fig. 765), as seen in one of the spirally-coiled Ammonoids, have the following arrangement: In the middle of the convex or ventral side of the shell is a single unpaired lobe, which is traversed mesially by the siphuncle, and is termed the "external," "ventral," or "siphonal" lobe (D). The lobe on each side of this (L) is known as the "superior-lateral lobe." The lobe on each side next to this again (E) is the so-called "inferior-lateral lobe"; and the lobes which follow this (of a variable number) are distinguished as the "auxiliary lobes" (A^1, A^2, A^3, A^4). Lastly, there is a second unpaired lobe immediately opposite to the ventral lobe, placed upon the concave side

of the shell, and known as the "internal," "dorsal," "antisiphonal," or "columellar" lobe. The "saddles" are similarly subdivided and distinguished. Between the ventral and superior-lateral lobes comes the "external saddle" (s D). Next to this, between the superior-lateral and inferior-lateral lobes, is placed the first "lateral saddle" (s L), followed on each side by a variable number of "auxiliary saddles" (s^1, s^2, s^3, s^4).

Associated with various forms of Ammonoids, sometimes situated within the body-chamber of the shell, or at other times wholly detached, are found the peculiar bodies to which the name of "Aptychi" has been applied. A typical *Aptychus* (figs. 766, 767)

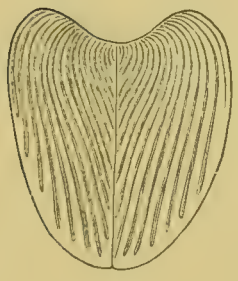


Fig. 766.—*Aptychus* (*Trigonellites*) *lamellosus*. Jurassic. (After Woodward.)



Fig. 767. — *Aptychus carinatus*, within the body-chamber of an Ammonite.

consists of two bilaterally symmetrical halves, which are somewhat semicircular in shape, and are apposed to one another by their straight inner margins, which are destitute of teeth. In some cases the *Aptychus* is thin and horny, but it is usually more or less extensively calcified, and its thickness is sometimes considerable. In the thick shelly types, the principal layer of the *Aptychus* has a peculiar cellular structure. The surface may be smooth or variously sculptured, and the inner face is commonly marked by concentric lines of growth. In the bodies to which the name of *Synaptychus* has been given, the general structure is similar to that of *Aptychus*, but the two halves of the structure are fused in the middle line. Bodies of this type have been found in the body-chamber of species of *Scaphites*. In *Anaptychus*, again, the structure is a thin, apparently horny, undivided plate, which is concentrically striated. Bodies of this nature have been found in association with certain forms of Ammonites and Goniatites. Some of the fossils which have been

described as the cephalic bucklers of Phyllocaridan Crustaceans (such as some of the forms referred to *Cardiocaris* and *Spathiocaris*) are in reality the "Aptychi" of Goniatites. Many theories have been held as to the nature of the "Aptychi" of the Ammonoids, but there are only two views which can be regarded as at all probable. On one of these views, the Aptychi are to be regarded as protective plates developed in the walls of the nidamental gland, in which case all examples of Ammonites possessing these structures are necessarily females. The more probable theory, however, is that put forward by Sir Richard Owen—viz., that the Aptychus is formed by the deposition of horny matter or lime within a structure corresponding to the "hood" of the existing Pearly Nautilus. On this view the Aptychus would act as an operculum, when the animal was withdrawn within the shell. In those Ammonoids which are devoid of Aptychi it must be supposed that the "hood" remained permanently uncalcified, as it does in the Pearly Nautilus.

As regards their *zoological affinities*, the Ammonoids have been generally regarded as belonging to the Tetrabranchiate division of the *Cephalopoda*, in which case the shell, like that of the Pearly Nautilus, must have been external. It has, however, been also held that the Ammonoids are really referable to the Dibranchiate division of the Cephalopods, in which case the shell, like that of the existing *Spirula*, must have been internal. The grounds for this view are chiefly derived from the mode of development of the shell of the Ammonoids, which resembles that observed in *Spirula* —the protoconch being in each case inflated and destitute of a cicatrix, while a "prosiphon" is present. The "Aptychi" of the Ammonoids have also been compared to the "nuchal cartilages" of the Cuttle-fishes. Upon the whole, however, the balance of evidence is in favour of the reference of the Ammonoids to the *Tetrabranchiata*—the groups of the *Clymeniidæ* and *Goniatitidæ* affording a transition between the two great sections of the *Ammonoidea* and *Nautiloidea*.

As regards the general *distribution in time* of the *Ammonoidea*, the most ancient types of the group belong to the genus *Goniatites*, in the wide sense of this name, and are found in the highest Silurian and the lowest Devonian deposits. The genus *Clymenia*, which, like *Goniatites*, is comparatively simple in morphological type, is also found in Devonian strata. The earliest forms of the "Ammonites" are found in the Permo-Carboniferous rocks of India, but in other regions the earliest representatives of this great section of the Ammonoids appear in the Trias. In the Mesozoic period the Ammonoids undergo a vast development, the principal and most widely distributed type being that of the "Ammonites." In the Cretaceous rocks, however, numerous new and varied

generic types are found, such as *Baculites*, *Hamites*, *Turrilites*, *Ptychoceras*, &c. With the close of the Cretaceous period, the entire group of the *Ammonoidea* underwent an apparently sudden and all but complete extinction, no undoubted examples of this division of Cephalopods being known in any unequivocal Tertiary strata, with the exception of certain "Ammonites" which have been found in the Eocene deposits of California.

In the following brief summary of the families of the *Ammonoidea* the arrangement adopted by Zittel has been adhered to :—

Family 1. Clymeniidæ.—In this family the suture-lines show simple lobes and saddles (fig. 768); the septal "necks" are directed backwards, the shell being "retrosiphonate"; and the siphuncle is placed on the internal side of the shell.

The only genus included in this family is *Clymenia* itself (fig. 768), in which the shell is coiled into a flat spiral, the whorls of which are in contact. The inner side of each whorl is deeply excavated for the reception of the convexity of the preceding whorl, and the inner coils of the spire are exposed to view. The body-chamber is long; the aperture has a ventral sinus; and the surface is smooth or marked with fine transverse striæ. The sutures are simply folded or lobed, and the siphuncle is marginal, and is placed on the internal or concave side of the shell. The septal "necks" resemble those of the Pearly Nautilus in being directed backwards, and they are sometimes short, or at other times invaginated into one another. The protoconch resembles that of the *Goniatitidæ* in form, and is without a cicatrix. The known species of *Clymenia* are confined to the Upper Devonian rocks, some of the limestones of this age in Germany being spoken of as the "Clymenienkalk," owing to their being profusely charged with fossils of this genus.

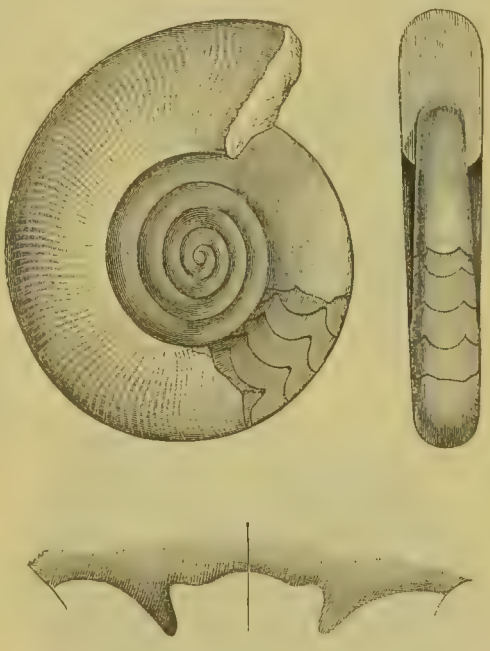


Fig. 768.—*Clymenia Sedgwickii*. Devonian. The lower figure shows the form of the suture.

Family 2. Goniatitidæ.—In this family the shell is spirally coiled, with more or less embracing whorls; the suture-lines are

simply lobed or angulated, and are not foliaceous; the septal "necks" are directed backwards; and the siphuncle is marginal, and is placed on the external side of the shell. The "protoconch" (fig. 744, D and E) is inflated, and is devoid of a cicatrix.

This family comprises the comprehensive genus *Goniatites*, which has been divided by Hyatt into a considerable number of generic groups, which need not be characterised here. In all the forms included under the general name of *Goniatites* the shell (fig. 769) is discoidal, the extent to which the inner turns are exposed varying widely in different forms. In some cases there is a wide umbilicus, and the inner volutions are extensively exposed; whereas in other forms the umbilicus is much reduced in size, and the last whorl more or less completely conceals those which preceded it. The body-chamber is usually long; and the surface is generally smooth, but may be adorned with tubercles or ribs. The sutures show simple, sometimes rounded, sometimes angulated lobes and saddles. The septal "necks" resemble those of the *Nautilidæ* and of *Clymenia* in being directed backwards, the shell being thus "retrosiphonate." On the other hand, the slender siphuncle resembles that of the Ammonites in being



Fig. 769.—*Goniatites* (*Gastrioceras*) *Yossæ*. Carboniferous.

marginally placed on the *external* side of the shell. In some cases simple or divided "Aptychi" have been shown to be present.

The genus *Goniatites*, using the name in the wide sense, com-

prises about three hundred species, all of which are confined to the Palæozoic rocks. The earliest types appear in the later Silurian deposits, and have very simple suture-lines. In the Devonian and Carboniferous rocks numerous forms of Goniatites are known; and the latest representatives of the group are found in the Permo-Carboniferous beds of the Salt Range in India. In certain of the Devonian and Carboniferous Goniatites the sutures become complicated by the increase of the number of lobes and saddles, till a near approach is made to the structure of the septa in the Ammonites.

Family 3. Arcestidæ.—In this family the shell is discoidal, and the body-chamber is very long, extending over one or one and a half whorls. The surface of the shell is smooth, or may be adorned with transverse striæ, ribs, or folds. The suture-lines show very numerous lobes and saddles, and both of these are laterally incised, thus becoming foliaceous (fig. 770). No "Aptychus" is present. [In some forms a horny "Anaptychus" appears to have existed.]

The members of this, as of all the remaining families of the *Ammonoidea*, are distinguished from the *Clymeniidæ* and *Goniati-*

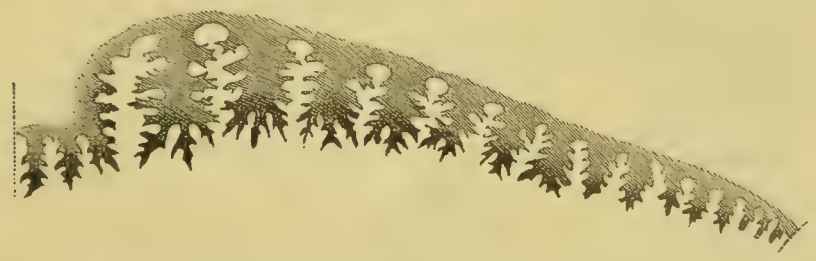


Fig. 770.—Suture of *Cyclolobus Oldhami*, one of the *Arcestidæ*. Permo-Carboniferous, India. (After Waagen—copied from Zittel.)

tidæ by the greater complexity of their septa and the more ornate form of the sutures resulting from this; while the septal "necks" are always turned forwards, and the shell is thus "prosiphonate." Formerly all these forms were grouped under a comparatively small number of genera, such as *Ceratites*, *Ammonites*, *Hamites*, *Turrilites*, *Baculites*, &c., distinguished principally by the mode of growth and the resulting form of the shell. By far the most important of these groups was the comprehensive genus *Ammonites*, embracing the great series of forms commonly known as "Ammonites." Through the researches of Hyatt, Neumayr, Mojsisovics, Waagen, von Zittel, and other well-known investigators, it has now been shown that the old genus *Ammonites* can no longer be maintained, but that the types formerly included under this name admit of a natural

division into a number of genera, which in turn constitute a number of distinct families. These modern divisions of the old genus *Ammonites* are distinguished by such morphological characters as the size of the body-chamber, the form of the sutures, the shape of the aperture, and the presence or absence of an "Aptychus." The mere *form* of the shell is a matter to which comparatively small weight is attached. Hence genera such as *Baculites*, *Turrilites*, and the like, in which the most obvious peculiarity is the external configuration of the shell, are now distributed, on the ground of their internal structure, among the different families into which the genus *Ammonites* has been broken up.

The three principal genera of the *Arcestidæ* are *Arcestes*, *Cyclolobus*, and *Lobites*. In the genus *Arcestes* the shell is involute, the last whorl being of large size, more or less completely concealing the inner whorls, from which it often differs in character. The umbilicus becomes constricted in course of growth, and is commonly completely closed by a callous deposit. The aperture is without lateral lobes, and the surface is smooth or furnished with fine transverse striæ. The species of *Arcestes* are almost exclusively Triassic, though early types (*Arcestes priscus*, Waagen) appear in the Permo-Carboniferous rocks of India, in which also is found the nearly allied genus *Cyclolobus* (fig. 770). The genus *Lobites* agrees with *Arcestes* in the general form of the shell, the long body-chamber, and the common closure of the umbilicus by a callosity. The surface, however, is commonly marked with radial folds (fig. 771), sometimes intersected by longitudinal striæ. The aperture may be simple, but is usually prolonged into a projecting hood. The species of this genus are confined to the Trias.



Fig. 771.—*Lobites delphinocephalus*. Trias.

Family 4. Tropitidæ.—In this family the shell is discoidal, with a long body-chamber, extending over more than one whorl. The surface is more or less richly ornamented, with radial ribs which often carry spines or tubercles. The sutures are foliaceous, the lobes and saddles being laterally incised. The principal genus of this family is *Tropites* itself, the species of which are found in the Trias principally, but survive into the Lias.

Family 5. Ceratitidæ.—In this family the form of the shell is variable, and its surface is ornamented with ribs or tubercles. The body-chamber is short, not extending over more than one-half or three-quarters of a volution. The sutures mostly show simple non-serrated "saddles," while the "lobes" are denticulated (fig. 772). The aperture is simple, and an "Aptychus" is not known to have been present.

The type of this family is the genus *Ceratites* (fig. 772), in which the shell is discoidal, the whorls in contact, and the inner volutions exposed to view. The lobes of the suture are denticulated or crenulated, while the saddles are simply rounded. The genus is characteristically Triassic, and the majority of the species are found in the Muschelkalk. In the Triassic genus *Trachyceras* (fig. 773) the general characters resemble those of *Ceratites*, but the saddles are in general laterally incised instead of being quite simple.

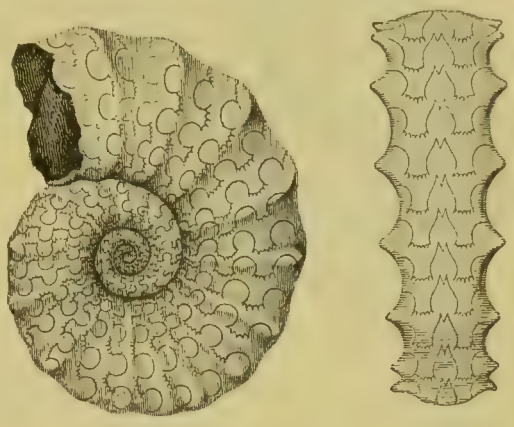


Fig. 772.—*Ceratites nodosus.* Muschelkalk (Middle Trias).

The preceding genera possess a discoidal shell, the whorls of which are in contact, but there are three Triassic genera included in this family in which the form of the shell is different. Thus, in *Choristoceras* the shell forms a flat spiral, the inner whorls of which are contiguous, while the last whorl is disjunct. In *Cochloceras*, again, the shell is turreted, while there is the additional peculiarity that the lobes, as well as the saddles, of the suture are simple. Lastly, in *Rhabdoceras* the shell is straight, the lobes of the suture being likewise free from denticulations.



Fig. 773.—*Trachyceras Aon.* Trias.

Family 6. Cladiscitidæ.—In this family the shell is discoidal, and the body-chamber is long, extending over one whorl or thereabouts. The shell is thick and laterally flattened, the surface being spirally striated or smooth. The suture shows foliaceous saddles and finely incised lobes. This family was founded by Zittel to include certain Triassic "Ammonites," most of which belong to the genus *Cladiscites* itself.

Family 7. Pinacoceratidæ.—The shell in this family has the form of a compressed disc, usually with a smooth surface. The body-chamber is short, occupying from a half to two-thirds of the

last volution. The suture has very numerous lobes and saddles, which are sometimes incised, sometimes comparatively simple, one or more adventitious lobes being usually present. An "Aptychus" is not known to have existed.



Fig. 774.—Side-view of *Phylloceras heterophyllum*. Jurassic.

The genus *Pinacoceras* itself includes a number of Triassic "Ammonites," which sometimes attain to a great size (a yard or more in diameter), and are distinguished by the extraordinary complexity of the suture-lines. On the other hand, in the genus *Sageceras*, though the sutures show very numerous lobes and saddles, this complexity does not exist, the saddles being tongue-shaped and entire, while the lobes are simply indented. The species of this genus are chiefly Triassic, but early types appear in the Permo-Carboniferous ("Salt-Range Group") of India.

Family 8. Phylloceratidæ.—In this family the shell (fig. 774) is discoidal, the body-chamber occupying from one-half to three-fourths of a volution. The surface is smooth or adorned with

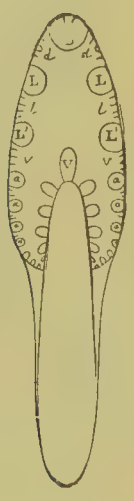


Fig. 775.—Outline of *Phylloceras heterophyllum*, showing the lobes and saddles. D, Siphonal lobe; L, Superior-lateral lobe; L', Inferior-lateral lobe; *a a*, Auxiliary lobes; V, Antisiphonal lobe; *d*, External saddle; *l*, Lateral saddle.



Fig. 776.—Suture-line of *Phylloceras heterophyllum*. D, Siphonal lobe; L, Superior-lateral lobe; L', Inferior-lateral lobe; *a a*, Auxiliary lobes; *d*, External saddle; *l*, Lateral saddle.

transverse striæ; and the aperture is simple. The lobes and saddles of the suture-line (fig. 776) diminish gradually in size in proceeding from the external towards the internal side of the shell;

and the saddles terminate in bladder-shaped rounded ends. An "Aptychus" is not known to have been present.

The type-genus of this family is *Phylloceras*, comprising involute "Ammonites," with a widely expanded body-chamber, a compressed form, and either no umbilicus or a small one (fig. 774). The surface usually exhibits fine transverse striæ, which are directed forwards; and the external margin is never keeled or tuberculated. The aperture is simple, with short ventral lobes. The most characteristic feature, however, is the presence of numerous saddles, which gradually diminish in size from without inwards, and which end in rounded or bladder-shaped extremities (fig. 776). The species of *Phylloceras* range from the Lias to the Cretaceous rocks, but the genus is preceded in the Trias by allied types (*Megaphyllites*).

Family 9. Lytoceratidæ.—Shell extremely variable in shape; the body-chamber in the coiled types occupying from two-thirds to three-quarters of the last volution. The surface is adorned with simple, wavy, or nodose ribs, which may be straight or bent. The



Fig. 777.—Suture-line of *Lytoceras Licbigi*, Jurassic. s, Siphonal lobe; es, External saddle.

suture-line exhibits few (generally six), deeply incised lobes and saddles; the superior, and commonly also the inferior, lateral lobe being divided into two symmetrical halves, while the saddles may also be more or less clearly bilateral (fig. 777). An "Aptychus" is only known in the single genus *Baculites* (Zittel).

The type-genus of this family is *Lytoceras* itself, which, like all the "Ammonites," possesses a discoidal shell. As shown, however, by Neumayr, the characteristic suture-line of *Lytoceras* is possessed by a number of forms, such as *Turrilites*, *Baculites*, *Hamites*, &c., in which the shell may be coiled into a turreted spiral, or may be straight, hook-shaped, &c. The shell in *Lytoceras* (fig. 778) is discoidal and widely umbilicated, the whorls contiguous but hardly or slightly overlapping. The surface is usually adorned with radial lines of growth, or periodic contractions of the shell, with corresponding prominent fringed ribs ("fimbriæ") at intervals. The aperture is simple, with an internal lappet resting on the preceding whorl. The suture-line (fig. 777) is complex, the lateral lobes

and saddles being divided into small symmetrical digitations. The species of *Lytoceras* range from the base of the Lias to the middle of the Cretaceous system.



Fig. 778.—*Lytoceras fimbriatum.* Lias.

The genus *Macroscaphites* (fig. 779) comprises a portion of the forms included in the old genus *Scaphites*, and the suture-lines agree with those of *Lytoceras* and its allies in the fact that the lateral lobes are divided into two symmetrical halves. The first portion of the shell is coiled into a flat spiral, the volutions of which are in contact, but the last-formed portion of the shell is disjunct and is prolonged in a straight line, its terminal extremity being bent upwards and backwards. The species of this genus are confined to the Lower Cretaceous rocks.

In the genus *Hamites* (fig. 780) the shell is an extremely elongated cone, which is bent upon itself more than once in a hook-like manner, all the volutions being separate. The surface is usually adorned with transverse ribs, and the body-chamber is very long. The suture resembles that of the *Lytoceratidæ* in the fact that the superior-lateral lobe (as also commonly the inferior-lateral lobe) is divided into two symmetrical halves, the saddles also being bilaterally symmetrical. The species of *Hamites* range from the Neocomian to the Chalk, and some forms attain a considerable size. The Cretaceous (Neocomian) genus *Hamulina* differs from *Hamites* in the fact that the elongated shell is only bent once, its two portions being parallel to one another but not in contact. In the genus *Ptychoceras*, again, the shell (fig. 781) has the form of a greatly elongated cone, which is once bent upon itself, the two straight portions of the shell being in contact. The thicker limb of the shell is transversely ribbed; and the sutures have the same form as those of *Hamites*. The species of *Ptychoceras* are exclusively Cretaceous, and range from the Neocomian to the Gault.

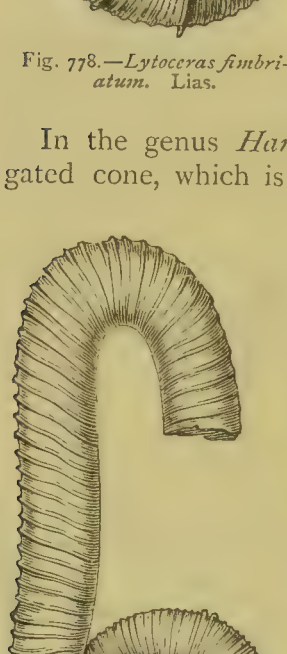


Fig. 779. — *Macroscaphites Ivanii.* Cretaceous. (Neocomian.)

In the genus *Turrilites* (fig. 782) the shell has the form of a

turreted spiral, being composed of volutions which pass obliquely round a central axis, an umbilicus being present or absent. The shell is usually sinistral, but is sometimes dextral. The surface is adorned with ribs or nodosities; and the lateral lobes of the suture-line are symmetrically divided. In *Turrilites* proper (fig.

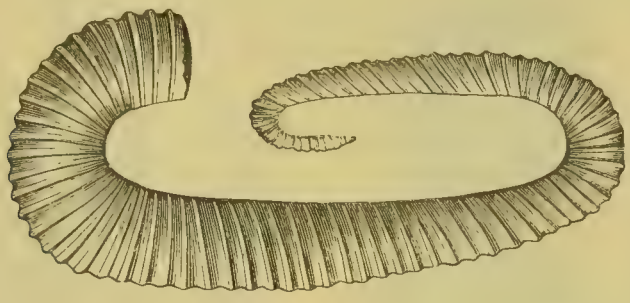


Fig. 780.—*Hamites rotundus*, restored. Cretaceous. (Gault.)

782) the volutions of the shell are in contact, whereas in *Helicoceras* the shell is coiled into an open spiral, the coils of which do not touch. Certain of the forms which have been placed in the genus *Heteroceras* (such as *H. polyplocum*) agree in the form of their sutures with *Turrilites*, from which they only differ in the fact that the terminal portion of the shell is coiled into an open spiral, the last whorl sometimes being prolonged in a straight line. All the types in question are Cretaceous, and range from the Neocomian to the Chalk.

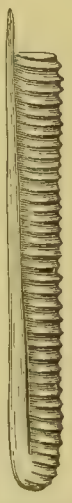


Fig. 781.—*Ptychoceras Emericianum*, reduced in size. Neocomian.

Lastly, the genus *Baculites* is included in the family *Lytoceratidæ* from the form of its suture-lines, the superior-lateral lobes being symmetrically divided. The shell in this genus (fig. 783) is in the form of a straight elongated cone, with a long body-chamber, the aperture of which is simple and is prolonged ventrally. In some forms a divided "Aptychus" has been shown to exist. The species of this genus range from the Neocomian to the highest beds of the Chalk.

Family 10. Ptychitidæ. — This family includes forms of "Ammonites," of variable shape, the spirally coiled shell being flat or ventricose, with a wide or narrow umbilicus. The body-chamber occupies from two-thirds to three-fourths of a volution. The sutures are sometimes simply angulated and resemble those of the Goniatites; or the saddles are

round and the lobes denticulated, as in *Ceratites;* or both saddles and lobes are incised. No "Aptychus" is present (Zittel).

The genera included in this family are mostly Triassic, the type-



Fig. 782.—*Turrilites catenatus.* The lower figure represents the entire shell; the upper figure represents the base of the shell seen from below. Gault.

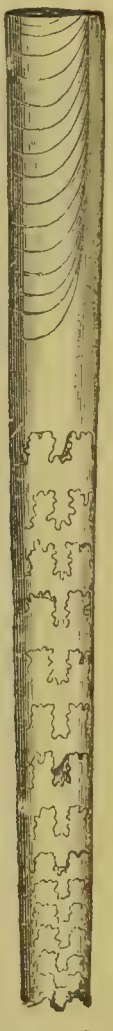


Fig. 783.—*Baculites anceps*, showing part of the body-chamber and a portion of the septal chambers. Chalk.

genus being *Ptychites* itself, in which the sutures have both the lobes and the saddles incised.

Family 11. Amaltheidæ.—This family includes "Ammonites," in which the shell is discoidal and laterally compressed (fig. 784, 785), and the last whorl conceals a considerable portion of the preceding volutions. The body-chamber occupies about two-thirds

of the last volution. The external side of the shell is acute, or is provided with a projecting keel, which is often hollow. The sutures are usually deeply incised, but may resemble those of *Ceratites* in form. A horny "Anaptychus" has been shown to exist in a number of forms.

The type-genus of this family is *Amaltheus* itself, in which the shell (figs. 784, 785) is furnished along its external margin with an

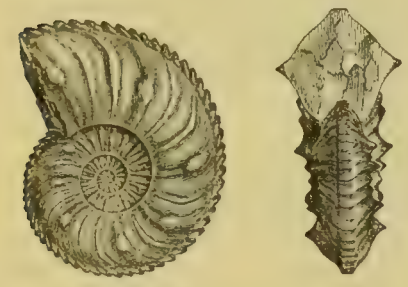


Fig. 784.—*Amaltheus* (*Ammonites*) *margaritatus*. Lias.



Fig 785.—*Amaltheus* (*Ammonites*) *cordatus*. Jurassic (Coral Rag).

acute or transversely plaited keel. The surface may be smooth, striated, or transversely ribbed. The aperture is furnished with a ventral process, and the sutures have deeply incised lobes and saddles. Numerous species of this genus are found in the Jurassic rocks, beginning in the Lias.

Nearly allied to the preceding is the genus *Schloenbachia* (figs. 786, 787), in which the external side is broad, and is furnished with a strong median keel, in the hollow of which the thick siphuncle is usually contained. The surface is transversely ribbed, and the aperture is falciform, and is provided on its ventral side with a forwardly directed process. The species of this genus are exclusively Cretaceous, and range from the Neocomian to the Chalk.



Fig. 786 — Side-view of *Schloenbachia Roissyana*. Cretaceous.



Fig. 787.—End-view of *Schloenbachia cristata*. Cretaceous.

In the Cretaceous genus *Buchiceras* the external edge of the shell is acute or keeled, but the sutures resemble those of *Ceratites* so closely that the forms of this type were formerly referred to the latter. Lastly,

the genus *Oxynoticeras* includes a number of Jurassic and Cretaceous "Ammonites," which differ from those comprised in *Amaltheus* chiefly in the form of the suture-lines.

Family 12. Ægoceratidæ.—The shell in this family of "Ammonites" is discoidal, compressed, and usually widely umbilicated; the surface generally with simple transverse ribs. The body-chamber occupies about three-fourths of the last volution, and the aperture is without lateral extensions. The suture is incised, with two lateral lobes, incompletely developed auxiliary lobes, and a bifurcated antisiphonal lobe. An "Anaptychus" is present (Zittel).



Fig. 788.—*Ægoceras capricornum*. Lias.

The type-genus of this family is *Ægoceras* (fig. 788), in which the surface shows simple transverse ribs spread out or split ventrally. The external side of the shell is rounded, without either a median keel or furrow. The species of this genus are confined to the Lias. The most important genus in this family is, however, *Arietites* (fig. 789), in which the shell is flat and discoidal, widely umbilicated, and many-whorled. The external margin is more or less flattened, and is provided with a median keel bordered by a lateral furrow on each side. The surface has simple straight ribs, which often have tubercles developed on them near the ventral margin. The body-chamber is long (fig. 762), and occupies one volution or more. A large number of species are known, all of which are confined to the Lower Lias, *A. Bucklandi*, *A. obtusus*, *A. bisulcatus*, and *A. rotiformis* being familiar species. If the name of *Ammonites* is to be employed at all as a generic designation, it must be for the forms here in question.



Fig. 789.—*Arietites* (*Ammonites*) *bisulcatus*, reduced in size. Lias.

Family 13. Harpoceratidæ.—In this family the shell (fig. 790) is discoidal, compressed, and umbilicated; the external margin is obtusely or acutely keeled; and the surface is adorned with falciform ribs or striæ. The aperture is falciform, and is furnished with rounded auricles and a long, pointed, ventral process. The suture is digitated, and the antisiphonal lobe is undivided. A calcified "Aptychus" is present.

The type of this family is the genus *Harpoceras*, of which very

numerous species are known, none of which transcends the limits of the Jurassic system. Familiar forms are the *H.* (*Hildoceras*) *bifrons*



Fig. 790.—*Harpoceras* (*Hildoceras*) *bifrons*. Lias.

(fig. 790) and *H. serpentinum* of the Upper Lias. Allied to *Harpoceras* is the Jurassic genus *Oppelia*, in which the shell is involute, and the umbilicus is much reduced in size.

Family 14. Haploceratidæ.—In this family the shell is discoidal, with a wide or narrow umbilicus; the external margin being rounded, or in a few cases feebly keeled. The surface is adorned with fine lines of growth or curved ribs, commonly with falciform constrictions or varices. The aperture has feebly developed auricles; the suture-line is deeply incised; and an "Aptychus" has hitherto been recognised in a few forms only.

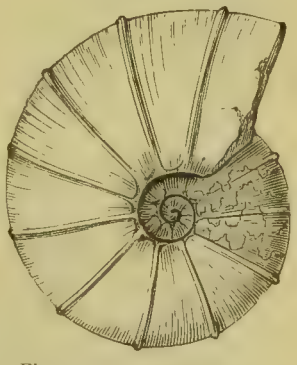


Fig. 791.—*Desmoceras* (*Ammonites*) *ligatum*. Cretaceous (Neocomian).

The family of the *Haploceratidæ* ranges from the Lower Jurassic rocks to the Chalk, and the principal genera are *Haploceras* and *Desmoceras* (fig. 791).

Family 15. Stephanoceratidæ.—The form of the shell in this family is variable, but the external margin is in general broad and rounded, and is never keeled; while the surface is almost always adorned with transverse ribs, which may carry tubercles, and usually bifurcate near the ventral border (fig. 792). The body-chamber occupies from one-half to two-thirds of the last volution. The aperture is commonly furnished with wide lateral extensions or lappets, which may be inflected to form a sort of cowl (fig. 763). The

lobes and saddles of the sutures are incised, and a calcified "Aptychus" is present.

In *Stephanoceras* itself (792) the shell is discoidal and usually widely umbilicated, and the surface is ornamented with strong ribs,

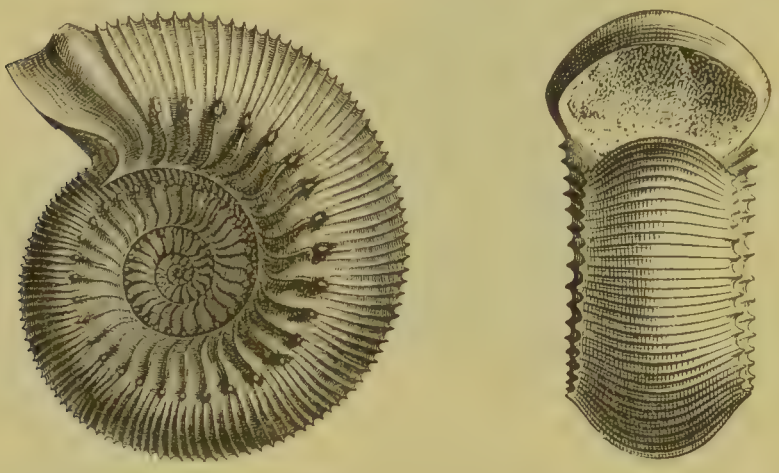


Fig. 792.—*Stephanoceras* (*Ammonites*) *Humphresianum*. Inferior Oolite.

which are simple internally, but become once or more divided on approaching the external border; the point of bifurcation being in general marked by the development of a more or less prominent



Fig. 793.—*Cœloceras* (*Ammonites*) *annulatum*. Lias.



Fig. 794.—*Cœloceras* (*Ammonites*) *commune*. Lias.

tubercle. The species of the genus are confined to the Jurassic rocks.

Very closely allied to the preceding is the genus *Cœloceras*, but the types included under this name have a long body-chamber (extending over more than one whorl), while the aperture of the shell

is simple and without side-lappets. The surface-sculpture is similar to that of *Stephanoceras*. All the species of *Cœloceras* are found in the Lias, two well-known forms being *C.* (*Ammonites*) *annulatum* (fig. 793), and *C.* (*Ammonites*) *commune* (fig. 794).

In *Cosmoceras* (fig. 795) the shell is discoidal and the surface-ribs are bent forwards, and often have tubercles or spines developed along their external ends. The aperture of the shell is furnished with long lateral extensions, which may disappear with age. The species of *Cosmoceras* are Jurassic and Lower Cretaceous.

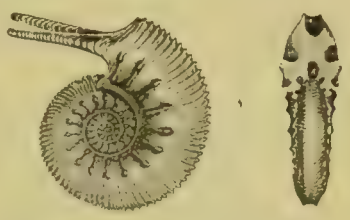


Fig. 795.—*Cosmoceras* (*Ammonites*) *Jason*, reduced in size. Jurassic (Oxford Clay).

In *Perisphinctes* (fig. 796) the shell is discoidal, and usually widely umbilicated, with a rounded external border. The surface-ribs divide, each, near the siphonal margin, into two or more branches. The body-chamber extends over two-thirds or the whole of the last whorl, and the aperture is simple, with lateral extensions or auricles.



Fig. 796.—*Perisphinctes* (*Ammonites*) *Martinsi*. Inferior Oolite.



Fig. 797.—*Hoplites* (*Ammonites*) *falcatus*. Cretaceous.

A very large number of species of this genus are known, ranging from the Inferior Oolite to the Lower Cretaceous.

In the genus *Hoplites* (fig. 797) the shell differs from that of *Perisphinctes* in being involute, with the umbilicus narrow, and the whorls high. The surface-ribs spring from tubercles near the umbilical margin, which divide as they proceed outwards, and are generally interrupted by a broad furrow along the line of the external border of the shell. The species of this genus are characteristic of the Cretaceous system.

In *Acanthoceras* the shell (fig. 798) is discoidal and umbilicated, and the sculpture consists of strong, straight, undivided, or divided

ribs, which increase in width in proceeding from the umbilicus towards the external margin, and are often adorned with tubercles. In the genus *Aspidoceras*, again, the shell (fig. 799) may be flat and widely umbilicated; or it may be inflated and involute, with a narrow umbilicus. The sculpture consists of one or two rows of tubercles, which occasionally become obsolete in late life, while ribs are as a rule only present in young examples. The numerous species of



Fig. 798.—*Acanthoceras Deverianum.* Cretaceous (Lower Chalk).



Fig. 799.—*Aspidoceras longispinum.* Jurassic (Kimeridge Clay).

Acanthoceras are wholly Cretaceous, while *Aspidoceras* ranges from the Middle Jurassic to the Lower Cretaceous. Allied genera are *Simoceras* and *Peltoceras*, both of which are confined to the Jurassic series.

All the preceding forms of the *Stephanoceratidæ* possess a spirally-coiled shell, the volutions of which are contiguous and lie in a single plane; and all belong to the great group of the "Ammonites." There are, however, other types, with a variously coiled shell, which, as judged by their general morphological characters, appear to be properly referable here. Amongst the types in question is the genus *Scaphites*, as restricted by the removal to the *Lytoceratidæ* of the forms which constitute the genus *Macroscaphites*. In *Scaphites* proper the shell (fig. 800) consists of a series of volutions coiled into a flat spiral, but having the last whorl detached from the others, produced, and ultimately bent back in the form of a crosier. The suture-line shows several auxiliary lobes; and an "Aptychus" is present. All the known species of *Scaphites* are confined to the Cretaceous system.



Fig. 800.—*Scaphites æqualis.* Upper Cretaceous.

In the genus *Crioceras* (fig. 801) the shell is rolled into a spiral,

the turns of which lie in one plane, but the volutions are not in contact with one another. The surface-sculpture consists of transverse ribs, usually with rows of tubercles or short spines. The suture is much ramified, but only consists of four principal lobes, viz., a siphonal lobe, superior-lateral lobe, inferior-lateral lobe, and



Fig. 801.—*Crioceras Emerici.*
Cretaceous.



Fig. 802.—*Heteroceras Emerici.*
Cretaceous.

antisiphonal lobe. The body-chamber is long, and the aperture is simple and without side-lappets. The species of *Crioceras* are Cretaceous, ranging from the Lower Greensand to the Gault. Some of the forms which have been placed under the genus *Heteroceras* appear to be nearly related to *Crioceras*. In these forms the first portion of the shell resembles *Turrilites* in being obliquely coiled and turreted, with contiguous whorls; but the last volution is detached from the rest, and is produced and recurved (fig. 802).

The forms for which the name of *Toxoceras* is employed have an elongated, arcuate or bow-shaped shell, which is not coiled into a



Fig. 803.—*Ancyloceras Matheronianum.* Gault.

spiral; and the structural characters agree with those of *Crioceras*. The species of *Toxoceras* are found in the Lower Cretaceous rocks; but it is not clear that the genus has not been founded upon broken examples of *Crioceras*.

Also very closely allied to *Crioceras*, if not absolutely identical with it, is the genus *Ancyloceras* (fig. 803), in which the shell agrees with that of the former in consisting in its earlier portion of several volutions, which are coiled into a flat spiral, but are not in contact with one another. The shell differs, however, from that of *Crioceras* in the fact that the last volution is produced at a tangent, and is ultimately bent back in the form of a crosier. The sutures are divided into six lobes, which are very unequal in size, and are digitated in a complex manner. The genus is Jurassic and Cretaceous, ranging from the Inferior Oolite to the Neocomian.

CHAPTER XLIV.

DIBRANCHIATE CEPHALOPODS.

The Dibranchiate Cephalopods or "Cuttle-fishes" are characterised as being *swimming animals, almost invariably naked, with never more than eight or ten arms, which are always provided with suckers. There are two branchiæ, which are furnished with branchial hearts; an ink-sac is always present; the funnel is a complete tube; and the shell (when present) is internal, or, if external, is not chambered.*

The Cuttle-fishes (fig. 804) are rapacious and active animals, swimming freely by means of the jet of water expelled from the funnel. The arms constitute powerful offensive weapons, being excessively tenacious in their hold, and being sometimes provided with a sharp claw in the centre of each sucker. They are mostly nocturnal or crepuscular animals, and they sometimes attain to a great size.

The general anatomy of the Cuttle-fishes has already been briefly discussed (see p. 821), and it only remains to allude shortly to certain points which possess a special palæontological interest. Under certain exceptionally favourable circumstances the outline of the body has been preserved in the fossil Dibranchiates, and in such cases the horny hooks with which the suckers are occasionally furnished may be recognisable, and it may even be possible to determine the number of the "arms." The mandibles of the Cuttle-fishes differ from those of the Tetrabranchiates in not being calcified, and these structures are therefore not preserved in the fossil condition. On the other hand, the Dibranchiates possess in the ink-sac a structure which is quite capable of petrifaction, the carbonaceous particles suspended in the "ink" being very indestructible. Hence the fossilised ink-bag of the Dibranchiates is of tolerably frequent occurrence.

The skeleton in the Dibranchiates may be rudimentary or wholly absent, as in the majority of the Octopods. In the female Argonaut, again, there is a delicate, involute, *external* shell, which is

secreted by the two dorsal arms, and has no connection with the mantle of the animal. In the great majority of the Dibranchiates, however, there exists an *internal* shell which is contained within the mantle, and varies in structure in different types. In some cases, the shell has the form of an elongated, horny, feather-shaped

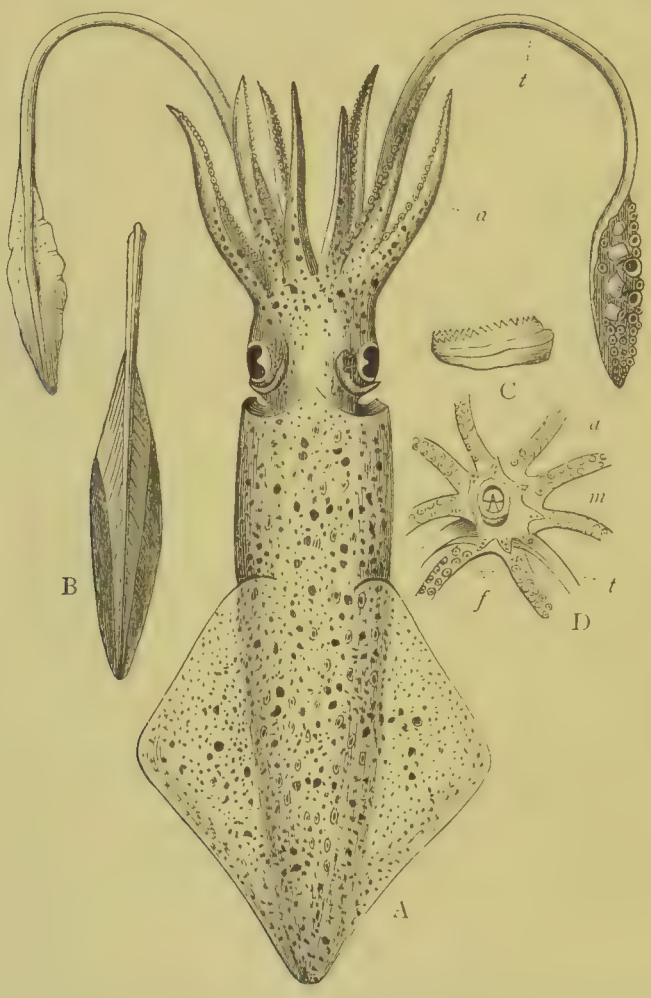


Fig. 804.—A, The Common Calamary (*Loligo vulgaris*), reduced in size; *a*, One of the ordinary arms; *t*, One of the longer arms or "tentacles." B, Skeleton or "pen" of the same, one-fourth natural size (after Woodward). C, Side-view of one of the suckers, showing the horny hooks surrounding the margin. D, View of the head from in front, showing the bases of the arms (*a*) and tentacles (*t*), the mouth (*m*), and the funnel (*f*).

body or "pen" (fig. 737, *b*), which is situated dorsally in a closed sac of the mantle. In other cases, as in *Sepia* (fig. 737, *a*) the internal shell is calcareous in composition. The posterior end of this skeleton may exhibit in a rudimentary form a chambered sac or "phragmacone," but in many cases no trace of this structure can

be detected. In the extinct family of the *Belemnitidæ*, the skeleton consists of a well-developed chambered cone (the "phragmacone"), which is divided by arched septa into a succession of air-chambers, the septa being pierced by a tube or "siphuncle." The phragmacone in this family is prolonged forwards on its dorsal side into a flattened "pen" (the "pro-ostracum"), while it is protected posteriorly by a solid calcareous investment or sheath (the "guard"). In the existing genus *Spirula* the shell is internal, but is reduced to the chambered "phragmacone," which is coiled into a flat spiral, the coils of which are not in contact (fig. 737, *c* and *d*).

The phragmacone commences in a globular or inflated "protoconch" or "initial chamber" (fig. 805, *pr*), which is distinctly constricted off from the first air-chamber, and which is devoid of a cicatrix. The siphuncle commences as a cæcal tube (*c*) pushed into the protoconch; and a "prosiphon" (*p*) is present. It will be thus seen that the protoconch of the Dibranchiates is essentially similar to that of the Ammonoids, a fact which has led some naturalists to the belief that the latter are truly Dibranchiate, and that their shell was therefore internal. In all the Dibranchiates in which a phragmacone is completely developed, the siphuncle is constantly *ventral* in position, and in *Spirula* it is consequently placed along the concave side of the shell.

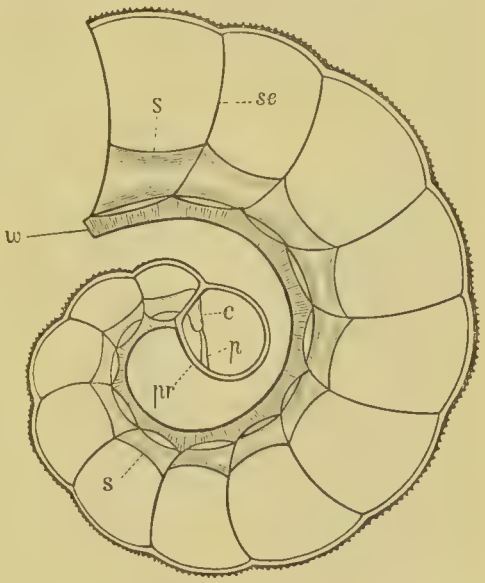


Fig. 805.—Longitudinal section of the shell of *Spirula Peroni*. *pr*, Protoconch; *p*, Prosiphon; *c*, Cæcal commencement of the siphuncle; *s s*, Siphuncle; *se*, One of the septa; *w*, Ventral wall of the shell. (After Munier-Chalmas.)

As regards their *classification*, the *Dibranchiata* are divided into two sub-orders, the *Octopoda* and the *Decapoda*, the former characterised by the possession of eight arms only, while in the latter there are eight comparatively short arms and two long arms or "tentacles." The *Decapoda* constitute the most important of these groups, and are divided by Fischer into the three sections of the *Phragmophora*, *Sepiophora*, and *Chondrophora*, in accordance with the nature of the skeleton.

As regards the distribution of the Dibranchiate Cephalopods in time, no Palæozoic types of the order have hitherto been detected.

The oldest known representatives of the order appear in the Trias, and belong to the extinct families of the *Belemnitidæ* and *Belemnoteuthidæ*. The *Belemnitidæ* show a great development in the Jurassic rocks, and in the same deposits occur the remains of Cuttle-fishes essentially similar to those now in existence (forms of the *Chondrophora*). The typical members of the *Belemnitidæ* disappear with the close of the Cretaceous period, but a few forms of this important Mesozoic family survive into the Tertiary. At the present day, the sole survivor of the section of the *Phragmophora* is the genus *Spirula*. The oldest types of the *Sepiophora* appear in the Tertiary deposits. In the following are given the characters and distribution in time of those families of the Dibranchiates which are known to occur in the fossil condition.

Sub-Order I. Decapoda.

The forms included in this sub-order invariably possess an internal shell, and the head is always furnished with eight equal "arms" and two longer "tentacles" (fig. 804, A). The mantle is usually furnished with lateral or terminal fins, and the suckers of the arms are pedunculate, or may be modified into horny hooks.

The sub-order is subdivided by Fischer into the three following families :—

1. *Phragmophora.*—Cuttle-fishes in which the skeleton is furnished with a "phragmacone," or chambered portion, in which a siphuncle is developed. *Ex. Spirula, Belemnites.*
2. *Sepiophora.*—Cuttle-fishes in which the skeleton is calcareous, but there is either no phragmacone, or a quite rudimentary one without a siphuncle. *Ex. Sepia.*
3. *Chondrophora.*—Cuttle-fishes in which the shell has the form of a horny "pen." *Ex. Loligo.*

Section A. Phragmophora.

In this section the shell consists of a "phragmacone," with or without certain accessory structures. The phragmacone (fig. 805) resembles the shell of the Tetrabranchiates in consisting of a succession of air-chambers separated by shelly partitions or "septa," which are perforated by a "siphuncle"; and it more particularly resembles the shell of the Ammonoids in the fact that the "protoconch" is inflated and is provided with a "prosiphon." The skeleton is, however, *internal*, and possesses also other peculiarities which are not found in the shell of any of the Tetrabranchiates. The only existing representative of this section is the genus *Spirula*, but numerous fossil forms are known. The *Phragmophora* may be divided into the following three families :—

Family 1. Spirulidæ.—This family includes only the recent genus *Spirula* (fig. 737, *c* and *d*, and fig. 805), in which the shell is reduced to the phragmacone. This is coiled into a flat spiral, the coils of which are not in contact, and it commences in an inflated protoconch. The septa between the successive air-chambers are concave; and the siphuncle is marginal, and is placed on the ventral or concave side of the shell. The siphuncle is completely enclosed within a series of septal "necks," which are directed backwards, and are long enough to reach from one septum to another. No fossil representatives of the genus have hitherto been recognised. .

Family 2. Belemnitidæ.—In this family the shell has the form of a conical "phragmacone," with a ventral siphuncle (fig. 806, *a*), which is lodged within a solid fibrous calcareous sheath or "guard" (*b*), and which has its dorsal margin prolonged into a thin horny or shelly plate or "pro-ostracum" (*c*), corresponding with the "pen"

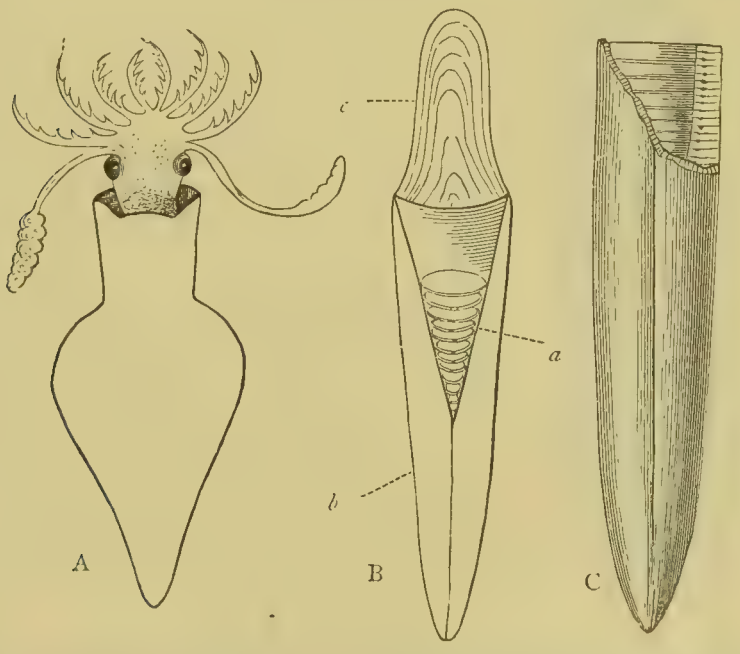


Fig. 806.—A, Restoration of the animal of the Belemnite; B, Diagram showing the complete skeleton of a Belemnite, consisting of the chambered phragmacone (*a*), the guard (*b*), and the horny pen (*c*); C, Specimen of *Belemnites canaliculatus*, from the Inferior Oolite. (After Phillips.)

of the *Chondrophora*. The arms in the *Belemnitidæ* were furnished with hooklets, and an ink-bag was present. The members of this family are all extinct, and range from the Trias to the Miocene Tertiary.

The most important genus in this family is *Belemnites* itself, in which the portion of the shell most commonly preserved is the

subcylindrical, conical, or fusiform "guard" or "rostrum." At its anterior broad extremity the "guard" is hollowed out into a conical excavation, termed the "alveolus" (fig. 807, *a*). Within the alveolus, in well-preserved specimens, is found the "phragmacone." This (fig. 807, *p*) consists of a conical series of chambers, enclosed in a thin proper wall (the "conotheca" of Huxley), and separated from one another by curved shelly partitions or "septa," which are perforated by apertures for the passage of the "siphuncle." The siphuncle is marginal, and traverses the middle of the ventral wall of the phragmacone. The outer or anterior chamber of the phragmacone is of tolerably large size; and the conotheca is prolonged forwards on its dorsal side into a horny or more or less calcified plate, known as the "pro-ostracum." This corresponds with the "pen" of the ordinary Cuttle-fishes, and from its extreme tenuity is never perfectly preserved, and, indeed, is completely wanting in the great majority of specimens.



Fig. 807.—Diagram of Belemnite (after Professor Phillips). *r*, Horny or shelly pen or "pro-ostracum"; *p*, Chambered "phragmacone" in its cavity or "alveolus" (*a*); *g*, "Guard."

The "guard" of the Belemnites consists of prismatic calcareous fibres, which are directed perpendicularly to the surface, and radiate in all directions from an axial line, which is not strictly central, but is somewhat nearer the ventral than the dorsal side. The growth of the guard is effected by the deposition of successive conical layers or sheaths, which are secreted over the entire surface, but are thickest behind, and become gradually attenuated in front. The surface of the guard is smooth; or may be wholly or partially granulated or wrinked; or, again, may be marked with branched vascular impressions, which are especially conspicuous on the ventral side. In many cases a well-marked groove — the "ventral furrow" — runs from the edge of the alveolus backwards on the ventral side, extending for a short distance only, or reaching to the point of the guard (fig. 806, c). In many cases the apical portion of the guard shows two symmetrical grooves—the "dorso-lateral grooves"—which

diverge slightly and become shallower as they extend forwards, and which mark the dorsal side of the shell.

Between three and four hundred species of the genus *Belemnites* are known, the maximum development of the group taking place in the Jurassic rocks. The oldest forms appear in the Lower Lias, and the last in the Chalk, but the genus appears to have wholly died out with the close of the Cretaceous period.

According to Zittel, the following sections of the genus *Belemnites* may be recognised :—

1. *Acuarii.*—Guard conical, with two or three apical grooves, but without a "ventral furrow" or "dorso-lateral grooves." (*Ex. B. acuarius*, Upper Lias.)

2. *Canaliculati.*—Guard elongated, conical, or fusiform, with a deep "ventral furrow." (*Ex. B. canaliculatus*, Inferior Oolite, fig. 806, c.)

3. *Clavati.*—Guard elongated, more or less clavate posteriorly, without a "ventral furrow," but with well-marked lateral grooves. (*Ex. B. clavatus*, Lias.)

4. *Bipartiti.*—Guard slender, cylindrical, with or without a "ventral furrow," but with deep "dorso-lateral grooves." (*Ex. B. bipartitus*, Neocomian.)

5. *Hastati.*—Guard elongated, narrower in front, thicker behind, and terminating in a point posteriorly. A deep "ventral furrow" is present, together with shallow lateral grooves. (*Ex. B. hastatus*, Oxford Clay.)

6. *Conophori.*—Guard conical, pointed behind. No ventral furrow is present, but a corresponding furrow proceeds from the edge of the alveolus backwards on the dorsal aspect of the shell. Lateral grooves are wanting or feebly developed. (*Ex. B. conophorus*, Neocomian.)

7. *Dilatati.*—Guard short, laterally compressed, flattened or four-sided. A dorsal furrow, as in the preceding group, is present, and the lateral grooves are more or less developed. (*Ex. B. dilatatus*, Neocomian.)



Fig 808.—*Belemnitella mucronata.* Chalk.

Closely allied to *Belemnites* proper, and probably not generically separable, are the forms included under the name of *Belemnitella.* In these types (fig. 808) the guard is cylindrical, with a short pointed mucro behind. Two diverging dorso-lateral lines exist on each side; and there is a slit-like ventral furrow, which begins at the margin of the alveolus, but does not reach the hinder end of the same. The ventral side of the guard shows very well-marked vascular impressions. The known species of *Belemnitella* are confined to the Upper Cretaceous rocks.

The most ancient type of the *Belemnitidæ* is the genus *Aulacoceras*, which is found in the Upper Trias of the Alps. In this genus the guard is elongated and clavate in form, with a deep lateral groove on each side. The phragmacone is at least twice as long as the guard, and slowly increases in width anteriorly.

The siphuncle is marginal, enclosed in a calcareous sheath, and contracted where it pierces the successive septa. *Atractites*, also from the Alpine Trias, differs from *Aulacoceras* chiefly in the want of lateral furrows.

In the singular genus *Xiphoteuthis*, of the Lower Lias, the guard is cylindrical; the phragmacone is greatly elongated, and increases very slowly in width; and there is a narrow "pro-ostracum," which is at least five times as long as the guard.

In the Tertiary rocks, the family of the *Belemnitidæ* is represented by the genera *Belemnosis*, *Beloptera*, and *Spirulirostra*. The only known species of *Belemnosis* is found in the Eocene rocks (London Clay), and has a short obtuse guard, with a terminal pore. The phragmacone has horizontal septa and a marginal siphuncle. The genus *Beloptera* is also known by a single species only, and likewise occurs in the Eocene rocks. In this curious type the shell consists of two conical segments joined point to point, and further united by wing-like lateral expansions. The posterior portion of the skeleton represents the guard, while the phragmacone is lodged in the anterior portion.

Lastly, in the genus *Spirulirostra* (fig. 809) the skeleton consists of a triangular, pointed guard, which is hollowed out in front for the



Fig. 809.—*Spirulirostra Bellardii*. Miocene Tertiary.

reception of a chambered portion or phragmacone. This latter is spirally bent, and the septa are pierced along its concave or ventral side by a marginal siphuncle. The only known species of *Spirulirostra* is found in the Miocene deposits of Italy.

Family 3. Belemnoteuthidæ.—In this family the skeleton is internal, and resembles that of the *Belemnitidæ* in consisting of a "guard," a chambered "phragmacone," and a thin shelly "pro-ostracum." The guard is, however, reduced to a thin calcareous

layer, which invests the conical phragmacone. The members of this family are confined to the Upper Trias and the Jurassic rocks, and the principal genus is *Belemnoteuthis* (fig. 810) itself. In the Oxford Clay, specimens of *Belemnoteuthis* have been found in which the outline of the soft parts has been more or less perfectly preserved. From these it is known that the animal had eight arms, with two "tentacles," furnished with horny hooks. The hinder end of the body was furnished with terminal fins; and there was a large ink-sac situated a little in front of the phragmacone. The phragmacone itself seems to have reached to nearly one-third of the length of the body.

Section B. Sepiophora.

In this section of the Decapods the skeleton is internal and is calcareous, consisting of a well-developed "pro-ostracum," termin-

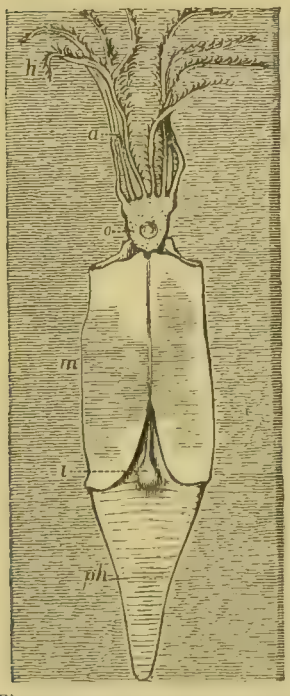


Fig. 810.—Restoration of *Belemnoteuthis*, from the Oxford Clay.

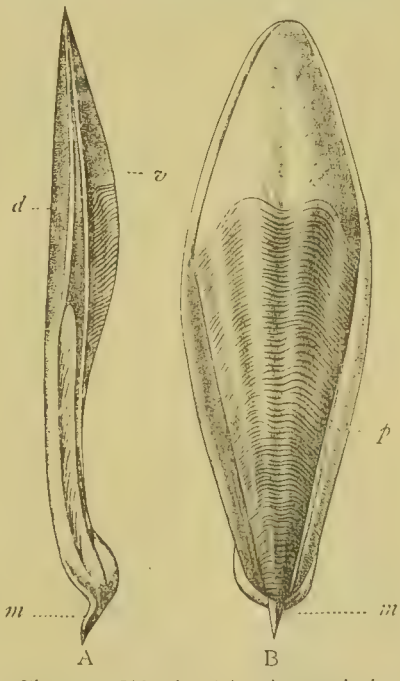


Fig. 811.—Side-view (A) and ventral view (B) of the shell of *Sepia Orbignyana*. *p*, "Pro-ostracum"; *m*, Mucro, hollowed out in front for the rudimentary phragmacone; *d*, Dorsal side of the shell; *v*, Ventral side. (After D'Orbigny.)

ating posteriorly in a rudimentary phragmacone and rostrum. No siphuncle is developed.

The type of this section is the existing genus *Sepia*, in which the shell ("sepion" or "sepiostaire") consists of an elongated, oval, calcareous "pro-ostracum" (fig. 811, *p*), which is rounded in front,

and terminates posteriorly in small pointed "mucro" (*m*). The front portion of the mucro is hollowed out, and contains a rudimentary "phragmacone," in which, however, a "siphuncle" is wholly wanting. The pro-ostracum forms the largest portion of the shell, and is thickened in front and concave on its inner side behind. The convex dorsal side is formed of two strata of comparatively dense calcareous tissue, partially separated by a chitinous lamella. The concave inner side, on the other hand, is formed of a large number of delicate parallel calcareous plates, which are not in contact, but are united by vertical pillars, giving rise to a spongy tissue, the spaces of which are filled by gases secreted by the animal. The rudimentary phragmacone is imperfectly chambered, and the minute "mucro" is the representative of the "guard" of the Belemnites.

A few fossil types of *Sepia* are known, the oldest appearing in the Eocene deposits. In the Eocene genus *Belosepia* the "sepion" is like that of *Sepia*, and has a short, slightly bent rostrum. Internally the rostrum is hollowed out for the reception of a chambered phragmacone, and on the inner side of this is an oblique funnel-shaped cavity, which is regarded by Munier-Chalmas as representing the siphuncle. Anteriorly the rostrum is continued into a calcareous pro-ostracum, the dorsal surface of which is rugose.

Section C. Chondrophora.

In this section of the Decapods the skeleton is internal, and has the form of a long, thin, pointed or feather-shaped "pen," which is not calcified, or only partially so, but is composed of a horn-like substance ("conchiolin").

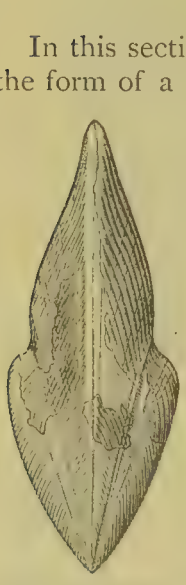


Fig. 812.—*Belotenthis subcostata.* Jurassic (Lias).

This section includes a large number of the commoner Cuttle-fishes of the present day, such as the familiar Calamaries (*Loligo*, fig. 804). Various fossil forms are also known from the Jurassic and Cretaceous rocks, the "pens" of these being often accompanied by the remains of the ink-sac. The fossil "pens" consist generally partly of horny and partly of calcified lamellæ, and some of them attain a considerable size. A number of genera have been founded upon these fossil pens, such as *Phylloteuthis*, *Beloteuthis* (fig. 812), *Geoteuthis*, *Leptoteuthis*, *Plesioteuthis*, &c.; but the differential characters of these are not of sufficient importance to require discussion here. In some of these types, as in *Plesioteuthis*, the pen is very long and sword-shaped, and is without lateral wings. More commonly, as in *Beloteuthis* (fig. 812), the pen is

more or less feather-shaped, and consists of a central shaft bordered by lateral wings. In some cases, as in *Leptoteuthis* and *Plesioteuthis*, the actual impression of the body of the animal is preserved, and from such examples it is known that the arms were not furnished with horny hooks.

Sub-Order II. Octopoda.

The forms included in this section of the Dibranchiates are characterised by the possession of eight equal arms, the internal skeleton being rudimentary or absent. The suckers of the arms may be modified into horny hooklets. In the female of the Paper Nautilus (*Argonauta*) the two dorsal arms are widely expanded, and secrete a delicate calcareous external shell, which is not connected by muscles with the body of the animal. The shell of the female Argonaut is one-chambered, spirally coiled and involute, its external border being keeled, and its surface tuberculated. The genus is represented in the Pliocene Tertiary by one or two species, and several living forms are known.

According to von Zittel, the genus *Acanthoteuthis* is founded upon the remains of an Octopod Cuttle-fish preserved in the fine-grained Lithographic Limestone (Jurassic) of Solenhofen, and showing the form of the body and the outline of the arms, the latter carrying each two rows of falciform horny hooks.

LITERATURE OF MOLLUSCA.

General.

1. "Manuel de Conchyliologie et de Paléontologie Conchyliologique." Paul Fischer. 1887.
2. "Handbuch der Palæontologie." Bd. I. Abth. 2, Lief. 1-3. 1881-84. Von Zittel.
3. "Manual of the Mollusca." S. P. Woodward. 4th ed., with "Appendix of Recent and Fossil Conchological Discoveries," by Ralph Tate. 1880.
4. "Handbuch der Conchyliologie." Philippi. 1853.
5. "Malacozoa." In 'Bronn's Klassen und Ordnungen des Thier-Reichs.' 1862-66. Keferstein.
6. "Traité élémentaire de Conchyliologie." 1835-39. Deshayes.
7. "The Genera of Recent Mollusca." 1858. H. and A. Adams.
8. "Mineral Conchology of Great Britain." 1812-30. J. Sowerby.

Lamellibranchiata.

[Apart from the general works above quoted, the following are some of the more important sources of original information, with more especial reference to the fossil forms.]

9. "On the Microscopic Structure of Shells." 'Reports of the British Association.' 1844 and 1847. W. B. Carpenter.

10. "Tegumentary Organs." 'Todd and Bowman's Cyclopædia of Anat. and Phys.' (Supplement). 1859. Huxley.
11. "Description des animaux sans vertèbres découvertes dans le bassin de Paris." 1860-66. Deshayes.
12. "Description des coquilles fossiles des environs de Paris." 1824-37. Deshayes.
13. "The Pelecypoda, with a Review of all known Genera of this Class, Fossil and Recent." 'Palæontologia Indica,' vol. iii. 1871. Ferd. Stoliczka.
14. "A Report on the Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri Country." 'U.S. Geol. Survey of the Territories,' vol. ix. 1876. Meek.
15. "Palæontology of New York." Vols. i.-v. (more especially vol. v.) 1843-85. Hall.
16. "Palæontology of Illinois." Vols. ii. and iii. 1866 and 1868. Meek and Worthen.
17. "British Palæozoic Fossils." 1851-1852. M'Coy.
18. "Geology of Yorkshire." 2d ed. 1836. Phillips.
19. "Faune du Calcaire Carbonifère de la Belgique." Part 5. 1885. De Koninck.
20. "The Palæozoic Conchology of Scotland." 'Proc. Roy. Physical Soc. Edin.' 1882. R. Etheridge, jun.
21. "A Monograph of the Crag Mollusca." Part ii., Bivalves. 'Palæontographical Society.' 1851 and 1856. Searles V. Wood.
22. "A Monograph of the Eocene Mollusca." Parts i.-iii., Bivalves. 'Palæontographical Society.' 1861, 1864, and 1870. Searles V. Wood.
23. "A Monograph of the Mollusca of the Great Oolite." Part iii., Bivalves. 'Palæontographical Society.' 1854. Morris and Lycett.
24. "Supplementary Monograph on the Mollusca from the Stonesfield Slate, Great Oolite, Forest Marble, and Cornbrash." *Ibid.* 1863. Lycett.
25. "A Monograph of the British Trigoniæ." *Ibid.* 1872-1876. Lycett.
26. "A Monograph of the Permian Fossils of England." *Ibid.* 1850. King.
27. "Structure and Affinities of the Hippuritidæ." 'Quart. Journ. Geol. Soc.,' vol. x. 1854. S. P. Woodward.
28. "Système Silurien du Centre de la Bohême." Vol. vi. (Ordre des Acéphalés.) Barrande. 1881.
29. "Die Bivalven der Gosaugebilde in den nordöstlichen Alpen." 'Denkschriften der k. Akad. der Wiss,' vol. xxv. 1866. Von Zittel.
30. "Die Fauna der Schichten von St Cassian." *Ibid.*, vol. xxv. 1866. Laube.
31. "Die Land- und Süss-Wasser-Conchylien der Vorwelt." 1870-75. F. Sandberger.

Gastropoda (including Pteropoda).

32. "Cretaceous Gasteropoda of Southern India." 'Palæontologia Indica.' 1868. Stoliczka.
33. "On the Silurian Gastropoda and Pteropoda of Gotland." 'Kongl.

Svenska Vetenskaps-Akad. Handlingar.' Bd. 19. 1884. Lindström.
34. "Faune du Calcaire Carbonifère de la Belgique." (Parts iii. and iv.) 1881 and 1883. De Koninck.
35. "Petrefactenkunde Deutschlands." Bd. vii. (Gasteropoden.) 1881. Quenstedt.
36. "Paléontologie française." 'Terrains Crétacés.' Vol. ii. 1842-43. 'Terrains Jurassiques.' Vol. ii. 1850. D'Orbigny. (With continuation by Piette. Vol. iii. 1867-82.)
37. "Die Land- und Süss-Wasser-Conchylien der Vorwelt." 1870-75. F. Sandberger.
38. "Mollusca from the Great Oolite." Univalves. 'Palæontographical Society.' 1850. Morris and Lycett.
39. "A Monograph of the British Jurassic Gasteropoda." 'Palæontographical Society.' 1887. Hudleston.
40. "A Monograph of the Eocene Mollusca." 'Palæontographical Society.' Part ii., Univalves. 1852, 1856, and 1858. Frederick E. Edwards.
41. "A Monograph of the Crag Mollusca." *Ibid.* 1848. (Part i., Univalves.) Searles V. Wood.
42. "Système Silurien du Centre de la Bohême. Vol. iii., Pteropodes. 1867. Barrande.
43. "Monographie der fossilen Pteropoden." 'Neues Jahrb. für Mineralogie.' 1847. G. Sandberger.
44. "Pteropoden aus dem Devon und Oligocän von Hessen und Nassau." 'Palæontographica.' Vol. xi. 1864. Ludwig.
45. "Palæontology of New York." Vol. v. Part ii. 1879. Hall.
46. "Report on the Pteropoda." 'Challenger Reports.' Vol. xxiii. 1888. Pelseneer.

Polyplacophora

47. "Report on the Polyplacophora." 'Challenger Reports.' Vol. xv. 1886. Haddon.
48. "On the Presence of Eyes in the Shells of certain Chitons, and on the Structure of these Organs." 'Quart. Journ. Micro. Sci.' New Ser., vol. xxv. 1885. Moseley.
49. "Faune du Calcaire Carbonifère de la Belgique." Part iv. 1883. De Koninck.
50. "On a New Species of Helminthochiton from the Upper Bala of Girvan, Ayrshire." 'Geol. Mag.' 1885. Henry Woodward.
51. "On the Silurian Gastropoda and Pteropoda of Gotland." 'Kongl. Svenska Vetenskaps-Akad. Handlingar.' Bd. 19. 1884. (Chelodes.) Lindström.

Scaphopoda.

52. "Anatomie et Monographie du genre Dentalium." 'Mém. Soc. d'hist. nat. de Paris,' t. ii. 1825. Deshayes.
53. "Histoire de l'organisation et du développement du Dentale." 'Ann Sci. Nat. Zool.' Ser. iv. Vols. vi.-viii. 1856-57. Lacaze-Duthiers.
54. "On the Cretaceous Dentaliidæ." 'Quart. Journ. Geol. Soc.' Vol. xxxiv. 1878. J. Starkie Gardner.

Cephalopoda.

55. "Mémoires pour servir à l'histoire et l'anatomie des Mollusques. (Cephalopodes.) 1817. Cuvier.
56. "Memoir on the Pearly Nautilus." 1832. Owen.
57. "Système Silurien du Centre de la Bohême." Vol. ii. 1867-77. Barrande.
58. "Cephalopodes : Études générales." 1877. Barrande.
59. "Beiträge zur Entwickelungsgeschichte der fossilen Cephalopoden." 'Palæontographica.' Bd. xxvi. and xxvii. 1879-80. Branco.
60. "Embryology of the Tetrabranchiates." 'Bull. Mus. Comp. Zoology.' Vol. iii. 1872. Hyatt.
61. "Genera of Fossil Cephalopoda." 'Proc. Soc. Nat. Hist. Boston.' Vol. xxii. 1884. Hyatt.
62. "Petrefactenkunde Deutschlands." Abth. I. Die Cephalopoden. 1846-49. Quenstedt.
63. "A Monograph of the British Fossil Cephalopoda." (Part I. Introduction and Silurian Species.) 1882. J. F. Blake.
64. "Catalogue of the Fossil Cephalopoda in the Collection of the British Museum." Vol. i. 1889. A. H. Foord.
65. "Faune du Calcaire Carbonifère de la Belgique." Parts i. and ii. 1878 and 1880. De Koninck.
66. "Paléontologie française." 'Terrains crétacés.' 1840. 'Terrains Jurassiques.' 1852. D'Orbigny.
67. "Fossil Cephalopoda of the Cretaceous Rocks of Southern India." 'Palæontologia Indica.' 1865. Stoliczka and Blanford.
68. "Jurassic Fauna of Kutch." (Cephalopoda.) 'Palæontologia Indica.' 1871. Waagen.
69. "Salt Range Fossils." (Cephalopoda.) 'Palæontologia Indica.' 1879-80. Waagen.
70. "Beiträge zur Kenntniss der Cephalopoden-Fauna der Hallstädter Schichten." 'Denkschr. d. Wiener Akad.' Bd. ix. 1856. Von Hauer.
71. "Nachträge zur Kenntniss der Cephalopoden-Fauna der Hallstädter Schichten." 'Sitzungsberichte d. k. k. Akad.' Wien. Vol. xli. 1860. Von Hauer.
72. "Das Gebirge um Hallstadt." 'Abhandl. d. k. k. Geol. Reichsanstalt.' Bd. vi. 1873 and 1875. Mojsisovics.
73. "Die Cephalopoden der Mediterranen Trias-provinz." 'Abhandl. d. k. k. Geol. Reichsanstalt.' Bd. x. 1882. Mojsisovics.
74. "Cephalopoden der Stramberger Schichten." 'Palæontol. Mittheilungen aus dem Museum des bayr. Staates.' Bd. ii. 1868. Von Zittel.
75. "Cephalopoden der oberen deutschen Kreide." 'Palæontographica.' Bd. xxi. and xxiv. 1871, 1876. Schlüter.
76. "Der Jura." 1858. Quenstedt.
77. "Ueber Ammoniten." 'Sitzungsber. d. Wiener Akad.' 1865 and 1870. Suess.
78. "Ueber Kreide-Ammoniten." *Ibid.* 1875. Neumayr.
79. "Die Ammoniten der Kreide und die Systematik der Ammonitiden." 'Zeitschr. d. deutschen geol. Gesellsch.' Bd. xxvii. 1875. Neumayr.
80. "Palæontologische Mittheilungen." (Ueber jurassische Cephalopoden.) 1862. Oppel.

81. "Sur la Classification des Ammonites." 'Bull. de la Soc. Géol. de France.' 1873. E. Favre.
82. "Mollusca of the Chalk of England: Cephalopoda." 'Palæontographical Society.' 1853, 1854, and 1856. Sharpe.
83. "Monograph of the Eocene Mollusca of England: Cephalopoda." 'Palæontographical Society.' 1849. Edwards.
84. "A Monograph of the Lias Ammonites." 'Palæontographical Society.' 1880-85. Wright.
85. "A Monograph of the Inferior Oolite Ammonites." *Ibid.* 1887. Buckman.
86. "Report on the Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri Country." 'United States Geol. Survey of the Territories.' Vol. ix. 1876. Meek.
87. "Cephalopoda." In Tate and Blake's 'Yorkshire Lias.' 1876. J. F. Blake.
88. "Belemnites from the Oxford Clay." 'Phil. Trans.' 1844. Owen.
89. "Structure of Belemnites." 'Mem. Geol. Survey.' 1864. Huxley.
90. "Monograph of the Belemnitidæ." 'Palæontographical Society.' 1865-69. Phillips.
91. "Observations on some Belemnites and other fossil remains of Cephalopoda in the Oxford Clay, near Trowbridge, Wiltshire." 'Phil. Trans.' 1848 and 1850. Mantell.
92. "Bemerkungen zur näheren Kenntniss der Belemniten." 1830. Graf Münster.

END OF THE FIRST VOLUME.

PRINTED BY WILLIAM BLACKWOOD AND SONS

*Fa 6.27

A

MANUAL OF PALÆONTOLOGY

A

MANUAL OF PALÆONTOLOGY

FOR THE USE OF STUDENTS

WITH A GENERAL INTRODUCTION ON THE
PRINCIPLES OF PALÆONTOLOGY

BY

HENRY ALLEYNE NICHOLSON

M.D., D.Sc., F.G.S., ETC.

REGIUS PROFESSOR OF NATURAL HISTORY IN THE
UNIVERSITY OF ABERDEEN

AND

RICHARD LYDEKKER

B.A., F.G.S., ETC.



THIRD EDITION
REWRITTEN AND GREATLY ENLARGED

IN TWO VOLUMES

VOL. II.

WILLIAM BLACKWOOD AND SONS
EDINBURGH AND LONDON
MDCCCLXXXIX

CONTENTS OF THE SECOND VOLUME.

PART III.—PALÆOZOOLOGY.

VERTEBRATA.

CHAPTER XLV.

PAGE

General characters of the Vertebrata—Division of the Vertebrata into classes—Exoskeleton—Teeth—Endoskeleton—Vertebræ—Skull—Limbs—Pectoral and pelvic girdles—Use of generic terms, ... 889-910

CHAPTER XLVI.

General characters of Pisces—Division into orders—Scales—Fins—Teeth—Vertebræ—Tail—Skull—Limbs—Distribution in time—Mutual relations of the orders—Conodonts, . . 911-922

CHAPTER XLVII.

The Cyclostomi—Characters of the Elasmobranchei—Characters of the Ichthyotomi—Families of the Ichthyotomi—Characters of the Selachii—Tectospondyli and Asterospondyli—Families of the Selachii—Ichthyodorulites, ... 923-948

CHAPTER XLVIII.

Characters of the Chimeroidei—Families of the Chimeroidei—Characters of the Dipnoi—Families of the Dipnoi, . . 949-957

CHAPTER XLIX.

Characters of the Ganoidei — Suborders and families of the Ganoidei, ... 958-991

CHAPTER L.

Characters of the Teleostei—Suborders and families of the Teleostei—Literature of Pisces, ... 992-1017

CHAPTER LI.

General characters of the Amphibia — Orders of the Amphibia—Characters and families of the Labyrinthodontia—The Apoda—Characters and families of the Caudata—Characters and families of the Ecaudata—Literature of Amphibia, . . . 1018-1045

CHAPTER LII.

General structure of the Reptilia — Sauropsida — Classification of Reptiles—Geological distribution of Reptilia, . . . 1046-1052

CHAPTER LIII.

The Theromorphous branch of Reptiles—Characters of the Anomodontia—Relations, suborders, and families of the Anomodontia —The Placodontia—The Synaptosaurian branch of Reptiles and its characters—Relations of the Sauropterygia and Chelonia—Characters of the Sauropterygia—Families of the Sauropterygia—Characters of the Chelonia—Characters and families of the Athecate Chelonians—Characters and families of the Testudinate Chelonians, ... 1053-1118

CHAPTER LIV.

The Streptostylic branch of Reptiles and its characters—Characters of the Ichthyopterygia—Genera of the Ichthyopterygia—Characters of the Proterosauria—Characters of the Rhynchocephalia — Suborders and families of the Rhynchocephalia—Characters of the Squamata — Suborders Lacertilia — Rhiptoglossa — Dolichosauria — Pythonomorpha — Ophidia — Families of the Squamata, ... 1119-1149

CHAPTER LV.

The Archosaurian branch of Reptiles and its characters—Characters of the Dinosauria—Suborders and families of the Dinosauria—Characters of the Crocodilia—Suborders and families of the Crocodilia—Characters of the Ornithosauria—Suborders and families of the Ornithosauria—Literature of Reptilia, . 1150-1207

CHAPTER LVI.

Characters of Aves—Distribution of Aves in time—Relations of the Ratitæ to the Carinatæ, ... 1208-1220

CHAPTER LVII.

Characters of the order Saururæ—Characters of the Ratitæ—Characters of the Carinatæ—Suborders and families of the Carinatæ—Literature of Aves, ... 1221-1244

CHAPTER LVIII.

General structure of the Mammalia—Teeth of Mammalia—Skull—Vertebral column—Sternum—Pectoral limb—Pelvic limb—Distribution in time of Mammals—Mutual relations of the different orders—Phylogeny of Mammals, ... 1245-1262

CHAPTER LIX.

Characters of the Prototheria—Characters of the Monotremata—Families of the Monotremata—Characters and affinities of the Multituberculata—Families of the Multituberculata—Characters of the Metatheria—Characters of the Marsupialia—Suborders and families of the Marsupialia, ... 1263-1288

CHAPTER LX.

Characters of the Eutheria—Characters of the Edentata—Families of the Edentata—Characters of the Cetacea—Suborders and families of the Cetacea—Characters of the Sirenia—Families of the Sirenia, ... 1289-1311

CHAPTER LXI.

Characters of the Ungulata—Characters of the Artiodactyla—Families of the Artiodactyla—Characters of the Perissodactyla—Families of the Perissodactyla—Characters and families of the Toxodontia—Characters and families of the Condylarthra—Characters and families of the Hyracoidea—Characters and families of the Amblypoda—Characters and families of the Proboscidea, ... 1312-1410

CHAPTER LXII.

Characters of the Rodentia—Suborders and families of the Rodentia—Characters of the Carnivora—Characters and families of the Pinnipedia—The Carnivora Vera—Teeth of Carnivora Vera—Families of Carnivora Vera—Characters and families of the Creodonta, ... 1411-1453

CHAPTER LXIII.

Characters of the Insectivora—Suborders and families of the Insectivora—Characters of the Chiroptera—Suborders and families of the Chiroptera—Characters of the Primates—Suborders and families of the Primates—Literature of Mammalia, . 1454-1474

PART IV.—PALÆOBOTANY.

CHAPTER LXIV.

Classification of the Vegetable Kingdom—General succession of plants in time—Laurentian Graphite—Supposed Cambrian plants—The "Fucoids" of the older Palæozoic formations—Silurian and Devonian plants—Nematophyton (Prototaxites)—Sporangites—The Carboniferous and Permian plants—Structure of coal—The plants of the Mesozoic period—Tertiary plants, ... 1477-1487

CHAPTER LXV.

Characters of Thallophytes—Characters and divisions of Algæ—Diatomaceæ—Phycochromophycæ—Fucaceæ—Chlorosporeæ

—Characters and fossil forms of the Siphoneæ Verticillatæ—Florideæ—Corallines and Nullipores—Coccoliths and Coccospheres—Characeæ—Fossil Fungi and Lichens, . . 1488-1499

CHAPTER LXVI.

Characters of Cormophytes—Bryophyta—Mosses—Liverworts—Characters of Pteridophytes—Characters of Filicaceæ—Ophioglossaceæ and Marattiaceæ—Ferns (Filices)—Rhizocarps—Equisetaceæ—Lycopodiaceæ, ... 1500-1523

CHAPTER LXVII.

Characters of Phanerogams—Characters of Gymnosperms—Cycadaceæ—Nœggerathieæ and Cordaiteæ—Characters and fossil forms of Coniferæ, ... 1524-1537

CHAPTER LXVIII.

Characters of Angiosperms—Characters and fossil forms of Monocotyledons—Characters of Dicotyledons—Principal groups of the Dicotyledons and their distribution in time—Literature of Palæobotany, ... 1538-1560

APPENDIX, ... 1561-1570

INDEX TO GENERAL INTRODUCTION AND INVERTEBRATA, . 1571-1592

INDEX TO VERTEBRATA, ... 1593-1616

INDEX TO PALÆOBOTANY, ... 1617-1624

ADDENDA ET CORRIGENDA TO PART III.

Page 901, line 13 from bottom, *for* "Weinsheimer" *read* "Wiedersheim."

" 912, line 2 from top, *for* "Teleotomi" *read* "Teleostomi."

" 928, line 17 from top, *for* "*Hypocladodus*" *read* "*Hybocladodus*."

" 928, line 8 from bottom, *for* "*Scilliidæ*" *read* "*Scylliidæ*."

" 944. *Carcharopsis* is identical with *Dicrenodus* (p. 928).

" 945, line 6 from bottom, *before* "no basal" *add* "usually."

" 951. *Myriacanthus* has recently been made the type of a distinct family—the *Myriacanthidæ* (see Appendix).

" 955. *Ceratodus* has recently been recorded from the Stormberg beds of the Karoo system of S. Africa.

" 965. *Pnigeacanthus* is identified with *Oracanthus* (p. 947).

" 966, line 11 from top, *before* "very minute" *add* "usually."

" 966, line 5 from bottom, *dele* "minute."

" 967, line 4 from top, *for* "Carboniferous" *read* "Devonian."

" 969, line 9 from top, *dele* "and Carboniferous."

" 971, fig. 905, *for* "*Heberti*" *read* "*Hibberti*."

" 978. *Palæoniscus* occurs in the Stormberg beds of the Karoo system of S. Africa; and from the underlying Beaufort beds a fish allied to *Rhabdolepis* has lately been described as *Atherstonia*.

" 979. The name "*Platysomidæ*" should be amended to "*Platysomatidæ*."

" 988, line 22 from bottom, *dele* "as in *Belonorhynchus*." The genus *Belonorhynchus* has recently been described from the Australian Hawkesbury beds; while *Belonostomus*, or a closely allied form, is recorded from the Lameta Cretaceous of India.

" 989. *Hypsicormus* has been recently described from the Oxford Clay, and *Eurycormus* from the Kimeridge Clay of England.

" 1004, line 20 from bottom, *for* "*Saurinichthys*" read "*Taurinichthys*."

" 1033. A species of *Bothriceps* has been recently recorded from the Karoo system of S. Africa.

Page 1035. The name *Platyops* being preoccupied, may be changed to *Platyoposaurus*. The genus should apparently be included in the *Archegosauridæ*, since the vertebræ are described as rhachitomous.

" 1036. *Capitosaurus* also occurs in the Bunter. The superiority of size of *Capitosaurus* over *Trematosaurus* renders it more probable that the former is the same as *Chirosaurus* (p. 1039).

" 1036, 1037. The alleged occurrence of *Mastodonsaurus giganteus* and *Metopias* in the Rhætic rests on insufficient evidence. The latter genus is stated to have been recorded from the Continental instead of the British Rhætic.

" 1041, bottom line, *dele* " and may not improbably be identical with *Chelotriton*."

" 1043, line 8 from top, *for* " each " *read* " hind," *and for* " pes " *read* " same." *Alytes* occurs in the Miocene of Sausan (*Rana Troscheli*). *Latonia* (p. 1044), according to Cope, is not allied to *Ceratophrys*, but belongs to the *Discoglossidæ;* it also occurs in the Sausan Miocene. The *Palæobatrachidæ* appear to connect the *Pelobatidæ* with the Aglossa, as represented by the *Dactylethridæ*, or *Xenopodidæ* as they should properly be called,—*Dactylethra* being a synonym of *Xenopus*.

" 1044. The name *Cystignathidæ* should be replaced by *Leptodactylidæ*, *Cystignathus* being a synonym.

" 1057, line 8 from top, *before* " characterised " *add* " typically."

" 1057, line 17 from top, *before* " African " *add* " typical."

" 1058-61. Additional characters of many of the genera are given in the Appendix.

" 1059, line 4 from top, *for* " divided " *read* " undivided."

" 1059, line 7 from top, *for* " single " *read* " double."

" 1108. *Ocadia* is distinct from *Palæochelys*. See Appendix.

" 1117, line 10 from bottom, the name " *Cyclanorbinæ* " may be substituted for " *Emydinæ*," since the latter is preoccupied.

" 1126. Since *Ichthyosaurus platyodon* differs from all other species of *Ichthyosaurus* by the smooth and carinated crowns of its teeth (fig. 1028), it appears, on the whole, advisable to regard it as the type of a distinct genus, for which the name *Temnodontosaurus* is proposed.

" 1139. *Rhaphiosaurus* proves to be founded upon part of a jaw of *Pachyrhizodus* (p. 993).

" 1176, line 2 from top, *for* " Kimeridgian " *read* " Portlandian."

" 1179, line 18 from top, *after* " species " *add* " of the former."

" 1264, fig. 1130. A is a skull of *Manis*, and not *Echidna*, as stated.

" 1372, lines 16, 17, from top, *for* " *Limnotherium* " *read* " *Limnohyus*."

PART III.

PALÆOZOOLOGY

VERTEBRATA

BY

R. LYDEKKER

PART III.

CHAPTER XLV.

SUB-KINGDOM VERTEBRATA.

General Characters.

The Vertebrata, or highest types of the entire animal kingdom, are distinguished as a whole from all the preceding sub-kingdoms (collectively designated as the Invertebrata) by the general presence of an internal skeleton, and more especially of a cylindrical longitudinal axis, termed the notochord, which is usually replaced in the adult by a series of cartilaginous or bony segments collectively constituting the *vertebral column*. This axis, or column, separates the smaller dorsal or neural tube of the body from the larger ventral or visceral (hæmal) tube; and the body itself, together with its appendages, is always symmetrical to this axis, and is never externally divided into segments. Limbs may be completely wanting, but when present they never exceed two pairs, and are always turned away from the dorsal or neural aspect of the body.

That the Vertebrata have been derived from the Invertebrata at an extremely early epoch of the earth's history is practically certain; and, although we are unable to point to the direct ancestors of the sub-kingdom, yet we have an inkling of this relationship exhibited by the presence of a notochordal structure in the earlier stages of the Ascidians, while there are also certain features in the organisation of the Annelids suggestive of their being allied to the primitive stock whence the Vertebrates took their origin. Since, however, it is probable that these primitive types were soft animals, it is unlikely that any light will be thrown on the origin of Vertebrates by means of Palæontology; and if the problem is ever to be solved it will be by the aid of Embryology.

Leaving then the origin of Vertebrates as an unsolved problem, in the solution of which the palæontologist can have but little share, we may proceed to a brief survey of the classification and chief structural features of the Vertebrate sub-kingdom, so far as they concern the palæontologist.

For this purpose the sub-kingdom may be divided into five classes[1]—viz., Pisces or Fishes, Amphibia or Amphibians, Reptilia or Reptiles, Aves or Birds, and Mammalia or Mammals—of which some of the more important features, from the point of view of the palæontologist, will be mentioned under these respective heads.

The first and second classes have been brigaded together by Professor Huxley under the name of Ichthyopsida, and the third and fourth as Sauropsida; and these terms will frequently be found convenient. Other writers, again, from the absence or presence of certain structures during the course of development, group together the two first classes as Anamniota (Anallantoidea, or Branchiata), and the remaining three as Amniota (Allantoidea, or Abranchiata).

Since the hard parts of Vertebrates are those with which alone the student of Palæontology usually has to deal, it will generally be unnecessary in this work to make any allusion to the soft parts of the body. With, regard, however, to these hard portions, it is advisable to give an extremely brief sketch of the more important elements of the Vertebrate *endo-* and *exoskeleton* for the benefit of those readers who are unacquainted with the elements of Comparative Osteology. It must, however, be distinctly understood by all who desire to practically study the history and structure of extinct Vertebrates, that it is absolutely essential they should have that thorough knowledge of the osteology of the recent members of the sub-kingdom which can only be gained by familiarity with actual specimens, accompanied by patient and laborious study of the numerous works on the subject. The following sketch is, indeed, merely sufficient to enable the reader to understand the meaning of the terms employed in the sequel; and throughout the Vertebrata the limits of this work will necessarily permit of only some of the more salient features of the skeleton of the various groups being mentioned. It may also be observed that those groups which have wholly disappeared, or of which the palæontological and evolutionary history is of especial interest, are more fully treated of than those more or less exclusively confined to the later or present epochs, and of which the history is fully recorded in those works to which the term "Natural History" is usually restricted. In the majority of instances, again, space does not permit of allusion to species; but

[1] A sixth class — Leptocardii — is formed for the reception of the Lancelet (*Amphioxus*), with which the palæontologist has, unfortunately, no concern, as its past history is a blank.

in the case of very large genera, where the species differ considerably in essential characters, attention is in some instances directed to the more important specific types. The student must not, moreover, expect to find that every known genus of fossil Vertebrates, or even every family, is mentioned in the following chapters, of which the object is to enable him to gain a fair general knowledge of the past history, distribution, and leading structural features of the best known groups of the various classes.

Commencing with the outer skeleton or *exoskeleton* it may be observed that, as a rule, the palæontologist has but little to do with structures developed in the *epidermis*, or layer overlying the true skin or *dermis*, since these generally perish during the process of petrifaction. The scales of Lizards belong, however, to this layer, and their impressions are in some instances preserved; while in the Chelonia the boundaries of the horny shields, covering the bony shell, are in some instances the most important characters by which fossil specimens can be determined. Occasionally, again, as in the Solenhofen *Archæopteryx*, the feathers of Birds have left their impression in rocks of which the material is of a fine-grained structure; while still more rarely, as in the bony covering of some Glyptodonts, pits from which hairs or bristles once grew are preserved in a fossil state.

The *dermal* exoskeletal structures are of considerably more importance from a palæontological point of view; and it should be observed that in nearly all the classes there appears to have been a gradual tendency to the disappearance of the bony elements of this skeleton in the higher forms, this being especially marked in the case of Fishes. In the latter class the scales of all types, of which fuller mention will be made in the sequel, belong to the dermis, and in some forms there may be a complete dermal armour formed of imbricating scutes, as in *Callichthys* among the Siluroids, or, as in the Coffer-fishes (*Ostracion*), consisting of calcified scutes with their edges in apposition. Apparently the most primitive type of dermal armour in this class consists of small denticules supported on bony plates, and it has been found that such denticules are absolutely homologous with true teeth, of which we shall speak presently. The bony *fin-rays*[1] and *fin-spines* of Fishes are another development of the dermal skeleton, which will be noticed under the head of that class; although it may be observed here that many of the latter are closely allied in structure to teeth. Again, the dermal skeleton in many extinct Amphibians and Reptiles takes the form of a more or less complete armour, either on the ventral or the dorsal, and not unfrequently on both aspects of the body, con-

[1] These dermal fin-rays must not be confounded with the radial cartilages of the endoskeleton.

structed of solid bony *scutes*, which may imbricate or overlap one another, like the tiles on a roof, or may be firmly united at their edges by sutural union. Such an armour may also develop enormous bony spines, often attached to the skin by an expanded base which represents the scutes. In the latter class, again, the bony shells of the Testudinate Chelonia are formed partly of dermal elements, blended with others belonging to the endoskeleton to form a continuous whole; while in the Athecate division of the same order the whole of the protective armour is of dermal origin.

The so-called membrane bones of the skull, and the clavicular portions of the pectoral girdle, are likewise of dermal origin, and therefore properly belong to the exoskeleton; but their intimate connection with cartilage bones renders it more convenient to consider them with the endoskeleton.

Teeth, as belonging to the list of dermal structures, may be conveniently noticed here; and the importance of these organs to the palæontologist can scarcely be overrated, since from their extreme density they are more often preserved in a perfect condition than most other parts of the skeleton, and thus frequently form the only safe guide to the affinities of an extinct type. Teeth are composed of two or more earthy constituents, varying in their structure, and the amount of animal matter contained in them. The most important element is that known as *dentine* (fig. 813, *d*), which forms the greater portion of the body of most teeth, and consists structurally of extremely minute tubes, cells, and earthy particles. Some dentine is devoid of blood-vessels; but in other cases it is permeated by the latter, when it is known as *vascular*, or *vaso-dentine;* and both these structures may exist in a single tooth. In young teeth (fig. 813) the centre of the dentine mass is occupied by the vascular *pulp-cavity* (*pc*), which is open at the base; but in the adult this cavity is often totally obliterated, by the formation of what is known as *osteo-dentine*, which is a kind of vascular dentine passing imperceptibly into the structure of true bone. The second primary constituent is the *enamel* (*c*), which, when present, immediately overlies the dentine of the *crown*, or exposed portion of the tooth, and is the hardest known animal substance; it is composed of extremely minute prismatic fibres, generally running at right angles to the outer surface of the tooth. This substance is the least constant element in teeth, although it is very generally present in those of Mammals; among the Reptiles it is entirely wanting in the Ophidian Squamata, but is present in the Crocodilia. The

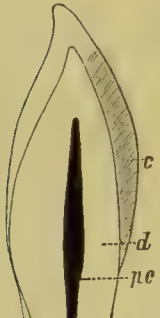


Fig. 813.—Diagrammatic vertical section of a tooth. *e*, Cement; *d*, Dentine; *c*, Enamel; *pc*, Pulp-cavity.

third constituent, usually known as *cement* (fig. 813, *e*), but occasionally as *crusta petrosa*, is the most external of the three: in some instances, as in fig. 813, it is confined to the *root*, or embedded portion of the tooth, where it consequently comes into immediate contact with the dentine; but in other cases it is found overlying the enamel of the crown, and in others again, where the enamel is wanting, it forms the main covering of the crown, as in the teeth of the Edentate Mammals. The cement is always traversed by vascular canals; and its structure is very similar to that of bone, although only occasionally presenting all the peculiarities of the latter.

True teeth are generally confined to the mouth and pharynx, but they may be situated on many of the bones of the former, and their mode of attachment varies from a simple anchylosis to the underlying bone, to implantation in distinct sockets. The simplest forms of teeth are small granular bodies, like the minute ossifications already mentioned as occurring in the skin of certain Fishes; while those of the most complex structure are to be found in certain Fishes (*Dendrodus*), in the Labyrinthodont Amphibians, and among Mammals in the Edentate genus *Orycteropus* and many Rodents and Ungulates. Except in forms where all are alike, as a general rule the teeth at the anterior extremity of the jaws are more or less simple, while there is a gradual increase in their complexity towards the opposite end, and in most cases the lower teeth are narrower and more elongated in an antero-posterior direction than the upper ones.

The importance of teeth to the palæontologist as a means of determining the affinities of fossil forms has been already mentioned; but in many cases their evidence must be supplemented either by that of other remains, or of the geological horizon whence they were obtained; since otherwise serious error may result. Thus, the teeth of the Dinosaurian *Megalosaurus* present a strong resemblance to some of those of the Mammalian *Machærodus;* while the front teeth of some Sparoid Fish approximate to those of the Primates; and the lower hinder teeth of the Kangaroos, of the Dinothere among the Proboscidea, and of the Tapir-like animals in the Perissodactyla, are all singularly alike in form. Another fertile source of error to be guarded against is the great difference in the form of the teeth from different regions of the mouth.

For the microscopic structure of teeth and their mode of development, the student must refer to other works; but a large number of the more important types of dental structure will be found noticed in the course of the following pages.

By far the greater number of adult Vertebrates possess a solid inner, or *endoskeleton*, composed of bone (into the nature of which

it will be unnecessary to enter here); but in others this skeleton remains cartilaginous throughout life, or, as in many Sharks, has solid structures formed by calcifications in the cartilage, which are quite distinct from true bone. This endoskeleton may be divided into an *axial portion*, or that of the head, trunk, and tail; and an *appendicular portion* supporting the limbs; the relations of the two being shown in fig. 814. The anterior part of the axial skeleton is formed by the *skull* (of which we shall speak later); and this is succeeded posteriorly by the *vertebral column*, typically composed of a number of segments, known as *vertebræ*, placed in the middle line of the dorsal side of the body, and continuing from the head to the extremity of the tail. This column is developed round a rod-like axis known as the *notochord*. In certain of the lower forms the latter may persist throughout life, and may either simply have a fibrous or cartilaginous sheath, or may have calcifications, or cartilages, in either the dorsal or ventral portion; and there is a complete transition from such a primitive type of column to that of the more specialised types in which the vertebræ are fully ossified. There is an enormous amount of variation in the structure of the vertebræ of different groups, and even in the different regions of the body of a single animal, but there is one general plan pervading them all. Thus a typical vertebra (fig. 815) consists of a basal portion, or *centrum*, which may be either disk-like or more or less elongated. Its posterior



Fig. 814.—Under surface of a Labyrinthodont Amphibian (*Seeleya*), with the dermal armour removed from the left side in order to show the endoskeleton. Greatly enlarged. (After Fritsch.)

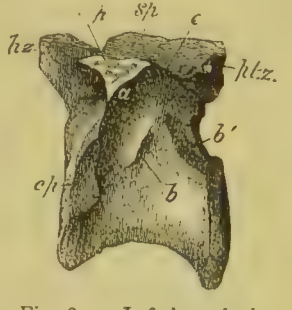


Fig. 815.—Left lateral view of an imperfect amphicœlous dorsal vertebra of a Dicynodont Reptile. *sp*, Neural spine (broken); *pz*, Prezygapophysis; *pt.z*, Postzygapophysis; *tp*, Transverse process (broken); *cp*, *Rib*-facet on the centrum; *b*, *b'*, Muscular ridges.

and anterior surfaces, by which (with the intervention of cartilages) it articulates with the adjacent centra, may be nearly flat or concave, when it is said to be *amphicœlous* (fig. 815); or its anterior surface may be more or less hollow, and the posterior convex (fig. 816), when it is termed *procœlous;* or, lastly, the reverse of the latter arrangement may obtain, when the centrum is termed *opisthocœlous;* an example of the latter structure being shown in the vertebra of *Calamospondylus* given in the sequel (fig. 1071). Immediately above the centrum is the aperture of the channel for the reception of the spinal cord, known as the *neural canal* (fig. 816); this canal being enclosed laterally and superiorly by the *neural arches*, which are surmounted by the *neural spine* (figs. 815, 816). The lateral portions of this arch are termed the *pedicles* (fig. 817, *n*), and the parts connecting the latter with the spine the *laminæ*. The arch, it should be observed, always ossifies separately from the centrum, and the line of junction between the two when, as in many Rep-

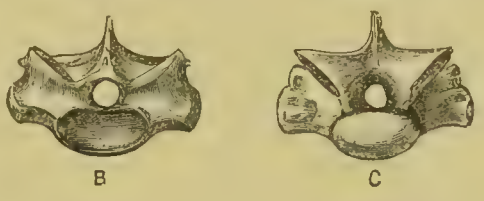


Fig. 816.—Anterior (B) and posterior (C) views of a procœlous dorsal vertebra of a Lacertian Reptile (*Varanus*). The part above B and C is the centrum; the aperture the neural canal, above and round which are the neural arches, surmounted by the neural spine; the oblique facets are the zygapophyses, and the lateral prominences the transverse processes, which are here very short.

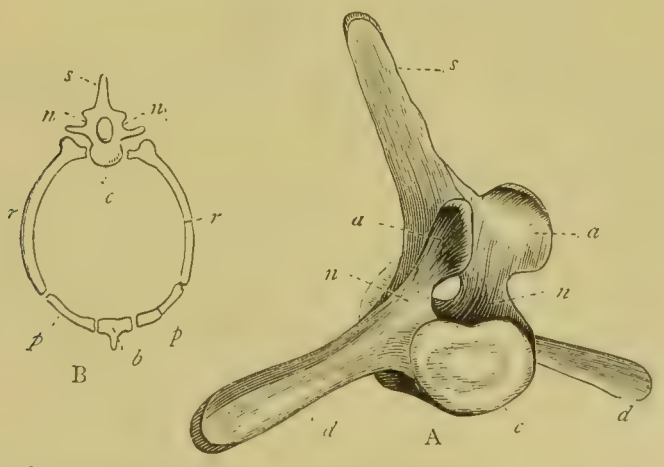


Fig. 817.—A, Oblique anterior view of the lumbar vertebra of a Whale. B, Diagrammatic transverse section of the bones of the thoracic region of a Mammal. Greatly reduced. *a*, Prezygapophyses; *b*, Sternum; *c*, Centrum; *d*, Transverse process; *n*, Pedicle of arch; *p*, Sternal rib; *r*, Rib; *s*, Neural spine. (After Owen.)

tiles, they remain distinct, is known as the *neuro-central suture*. The neural arch bears a pair of processes, or facets, at either extremity for articulation with the adjacent vertebræ; those at the anterior extremity (fig. 816, B) being known as *prezygapophyses*, and

looking inwards and upwards; while those at the other extremity (fig. 816, c) are termed *postzygapophyses*, and look downwards and outwards.[1] Besides these processes for mutual articulation, there are other processes on many vertebræ; the most constant being the *transverse processes*, or *diapophyses*, which may be very short as in fig. 816, or greatly elongated as in fig. 817, A, *d*. These transverse processes may arise either from the arch or from the centrum, and in the trunk frequently serve for the main attachment of the *ribs* (fig. 817, B). In fig. 816 we have an example of a vertebra with very short transverse processes placed mainly on the centrum, while in the vertebra of *Iguanodon*, figured in the sequel (fig. 1058), we see very large transverse processes arising solely from the arch.

The sides of the centrum in the anterior region of the body frequently carry other articular processes for the ribs, which may be termed rib or costal facets (fig. 815, *cp*), or *parapophyses*. Again, the inferior or hæmal surface of a vertebra may bear a *hæmal spine*—the term hæmal being applied to the inferior aspect on account of its being directed towards the heart and large blood-vessels. Each vertebral centrum carries its own arch; but between the true centra of the Ichthyopsida there may be intercalated centra-like bodies, carrying no arches, and termed *intercentra*. Rudiments of such intercentra occur in the so-called *wedge-bones* or *hæmapophyses*, found between the lower borders of the centra in certain Reptiles, and more especially between the first and second vertebræ. Further, the Y-shaped *chevron-bones*, usually articulating between adjacent vertebral centra in the tail of many Vertebrates, are also morphologically intercentral elements. In Fishes the vertebral column can only be divided into *trunk* and *caudal* regions; but in the majority of higher forms further divisions can be made. Thus the vertebræ of the neck, in which the ribs never articulate with the sternum, are termed *cervical* (fig. 818, *c*); the first of this series being designated the *atlas*, and the second the *axis*. It is further remarkable that in most instances the centrum of the atlas is not joined to its arch, but either remains as a distinct element, or becomes anchylosed to the front of the centrum of the axis to form the so-called *odontoid process*; and it appears that in the latter case the inferior bar connecting the two lateral arches of the atlas is really the remnant of the first intercentrum. It is, moreover, probable that this separation of the component elements of the atlas should be regarded as a retention of the primitive feature obtaining in the vertebral column of many extinct Fishes and Amphibians, where, as will be noticed below, the whole of the vertebræ are thus disintegrated. Finally, it has been suggested that certain bony

[1] These are well seen in the vertebra of *Calamospondylus* above mentioned.

splints overlying the arch of the atlas in Crocodiles represent a vertebra intercalated between the latter and the cranium, for which the name *proatlas* has been proposed. It is, however, by no means proved that these splints do not belong to the atlas vertebra, so that an authority like Mr Hulke is disposed to doubt the validity of this alleged additional vertebral segment.

In such Vertebrates as have the hind limbs well developed, one or more of the vertebræ in the hinder part of the trunk differs from the rest, and forms a *sacrum* (fig. 818, *s*), which articulates by anchylosed ribs with the pelvic girdle. The vertebræ forming the region between the sacrum and the last cervical vertebræ in the higher forms consist posteriorly of a *lumbar* series (fig. 818, *l*),

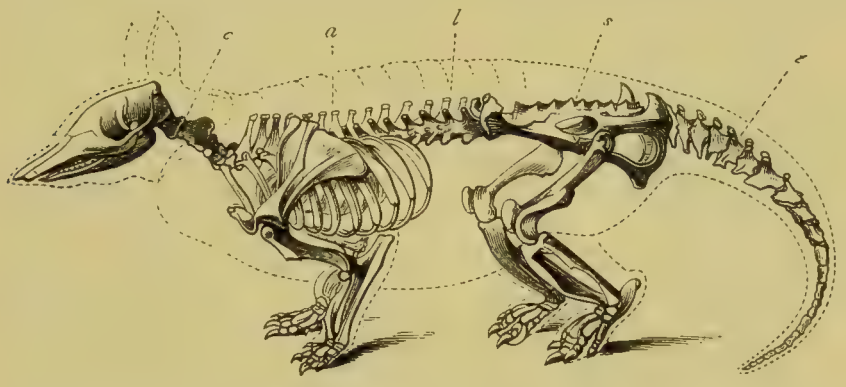


Fig. 818.—Skeleton of an Armadillo, showing the regions of the vertebral column. *c*, Cervical; *d*, Dorsal; *l*, Lumbar; *s*, Sacral; *t*, Caudal region or tail. The pectoral girdle is below *d*, and the pelvic below *s*. Reduced.

without or with very short ribs, and anteriorly of a *dorsal* series (fig. 818, *d*), provided with long ribs, of which the anterior ones articulate with the breast-bone or *sternum*. In many Amphibians, however, in which (as in many Reptiles) there is no sternum, the ribs continue throughout the lumbar and some of the caudal series, as in fig. 814, so that no distinction can be drawn between dorsals and lumbars, and the series between the cervicals and sacrals is consequently called *dorso-lumbar*. The term *caudal* is applied to all those vertebræ posterior to the sacrum. Moreover, where there is no sternum, it is frequently difficult to draw an exact demarcation between cervical and dorsal vertebræ, and we are compelled to rely on analogies drawn from the mode of articulation of the ribs.

Ribs, which have been already mentioned, are nearly always present in the dorsal region, and may occur throughout the length of the vertebral column. According to the views of Dr Baur, they are to be regarded as originally intervertebral structures, since they are attached in some of the earlier forms to the vertebral inter-

centra; but by the disappearance of the latter they have frequently become transferred to the centra or their appendages, although in other cases their original derivation is indicated by their articulation at the junction of two vertebræ. Very generally ribs articulate with the vertebral column by two distinct heads, which is probably the original primitive type of structure. In these cases the anterior or lower head is termed the *capitular*, and articulates with the rib-facet or parapophysis on the vertebral centrum (fig. 815, *cp*); while the posterior or upper head is known as the *tubercular*, and in the dorsal vertebræ articulates with the transverse process or diapophysis of the arch. In the dorsal ribs the two heads may, however, coalesce, and articulate with a facet on the centrum, or with a longer or shorter transverse process on the arch. Frequently, moreover, while the anterior dorsal ribs have double heads, the posterior ones have but a single head articulating with the transverse process. In the caudal region of many Reptiles true ribs articulate with the upper part of the centrum, and except as being separate, are indistinguishable from the caudal transverse processes of many Mammals, such as the Cetacea (fig. 817). Cervical ribs are present in most Reptiles, and usually articulate by two heads to the vertebræ — the upper head joining a facet, generally placed on the arch, corresponding to the transverse process of the dorsal vertebræ, and the lower one articulating to another facet on the centrum. Very rarely in Reptiles these cervical ribs may be completely anchylosed to the vertebræ, as in the vertebra of *Calamospondylus*, figured in the sequel (fig. 1071); and this suggests that at least a portion of the so-called transverse processes of the cervical vertebræ of Mammals, which arise from the vertebræ by double pedicles, really correspond to cervical ribs. In the Sauropterygia both heads of the cervical ribs articulate with the centrum.

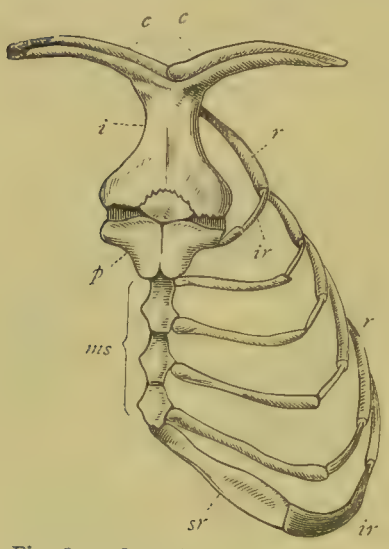


Fig. 819.—Sternal region of a young *Ornithorhynchus*. *c*, Clavicle; *i*, Interclavicle; *p*, Presternum; *ms*, Mesosternum; *r*, Rib; *ir*, Intermediate rib; *sr*, Sternal rib. (After Flower.)

When a sternum is present the distal ends of the dorsal ribs are generally unossified, and are sometimes termed *intermediate ribs* (*ir*, fig. 819); and these unossified elements unite distally with the sternal ribs (*sr*), which in their turn join the sternum (fig. 817, B, *b*). Further, among the Sauropsida lateral ossifications may be developed

on the ribs, termed *uncinate processes*, of which the position is shown in the figure of the skeleton of the Eagle given below (fig. 1106).

The breast-bone or *sternum* (figs. 817, 819) is usually composed of a median series of bones or cartilages on the ventral aspect of the body, which is divisible in the higher groups into an anterior *presternum*, usually consisting of a single ossification; and of a series of *mesosternal* elements, followed posteriorly by the *xiphisternum*. In many Sauropsida the sternal bones have long lateral processes; and the ossifications in this class may consist of a pair of bones united by cartilage.

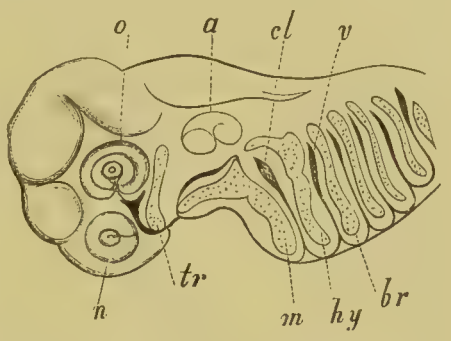


Fig. 820.—Left lateral view of the skull of an embryo Dog-fish. *tr*, Left trabecula; *n*, *o*, *a*, Nasal, orbital, and auditory capsules; *m*, *hy*, *br*, Mandibular, hyoid, and branchial arches; *cl*, *v*, Hyomandibular and first branchial clefts. (After Parker.)

The *skull*, or anterior termination of the axial skeleton, now claims our attention, but the description of this important and difficult part must be of the briefest. The researches of embryologists have shown that the skull is only a special modification of the primitive elements from which the rest of the axial skeleton were formed, although it does not consist, as was once thought, of a series of modified vertebræ. The skull is divisible into a dorsal, or *cranial*, and a ventral, or *visceral*, portion; the former, originating from a series of primitive segments (*somites*), encloses the brain-cavity; while the latter, which has a segmentation of distinct and later origin, is primitively connected with the function of respiration.

The earliest commencement of the primitive cartilaginous cranium occurs in the formation of a pair of rod-like *trabeculæ* (fig. 820), lying at the base of the brain, of which the posterior *parachordal* parts embrace the extremity of the notochord (fig. 821). These parachordals soon unite to form a *basilar plate* supporting the brain (fig. 821); while the anterior *prochordal* parts unite in front to enclose a space (*ibid.*, *ol*) for the passage of the olfactory nerves,

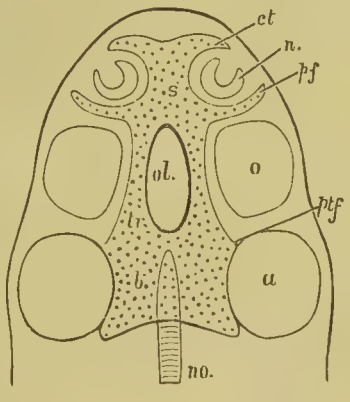


Fig. 821.—Upper view of a later embryo. *ct*, Cornu of trabeculæ; *pf* and *ptf*, Preorbital and postorbital processes of do.; *s*, Ethmonasal septum; *b*, Basilar plate; *no*, Notochord; *ol*, Olfactory foramen. Other letters as in fig. 820.

the united portion forming the *ethmonasal septum* (*ibid.*, *s*). By the approximation of the basilar plate to the *nasal*, *orbital*, and *auditory capsules*, these three distinct sense-regions become differentiated in the cranium; and while the first and third become enclosed in cartilage, the lateral borders of the basilar plate, in some instances, grow upwards to enclose the brain in a complete cartilaginous capsule, which in certain Sharks (fig. 822) persists throughout life. In the higher forms, however, the cartilage does not extend upwards over the brain, which becomes roofed in by bone formed directly from the overlying membrane.

The *visceral portion* of the skull is formed by cartilages arranged in a series of *arches* in the walls of the throat (fig. 820). In the Ichthyopsida there may be as many as nine of these *visceral arches*, but in the other three classes they become reduced in number to at most three or four, which are also functionally modified. The first arch (fig. 820, *m*) supports in all cases the walls of the mouth, and is accordingly called the *mandibular* arch; the second is termed the *hyoid;* while the remaining ones, which persist only in the adults of Fishes as supports of the gills or *branchiæ*, are termed *branchial.* It should further be observed that these arches are separated from

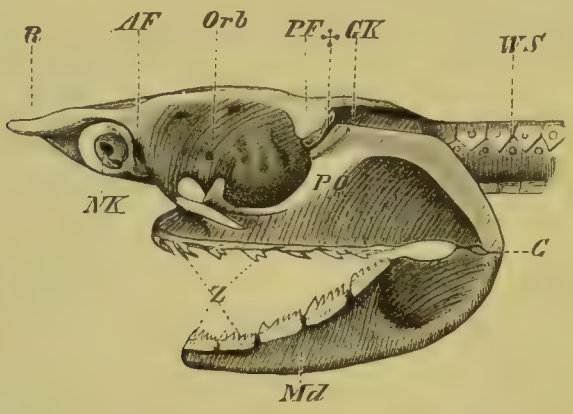


Fig. 822.—Left lateral view of the cartilaginous skull of a Shark (*Notidanus*), greatly reduced. *R*, Rostrum; *AF*, *PF*, Pre- and post-orbital processes; *Orb*, Orbit; *NK*, Nasal capsule; ÷, Articulation of palatopterygoid (*PQ*); *G*, Articulation of Meckel's cartilage (*Md*); *Z*, Teeth; *WS*, Vertebral column. (After Wiedersheim.)

one another in the embryo by a series of *visceral clefts* (fig. 820), of which the respiratory apertures of Sharks are remnants. The *mandibular arch* becomes divided into segments, consisting of a short proximal portion known as the *quadrate*, which very generally forms the main support of the lower jaw; and a long distal portion known as *Meckel's cartilage*, around which the *mandible*, or lower jaw, is subsequently formed in those forms which develop membrane bones, but which in the Sharks persists throughout life as the functional lower jaw

(fig. 820). The quadrate gives off an anterior *palatopterygoid* (*palatoquadrate*) bar, which in Sharks (fig. 822) persists to form a kind of false upper jaw. The hyoid arch, which is close to the mandibular, and which in Fishes may also take a share in the support of the mandible, is likewise segmented; the most important elements in the latter class being the *hyomandibular* and the *symplectic*, which are shown in an ossified condition in fig. 823, *hm*, *sy*. As already mentioned, in Sharks the primitive cartilaginous skull is complete, and persists in this condition throughout life; but in the great majority of Vertebrates the progress of chondrification is arrested,

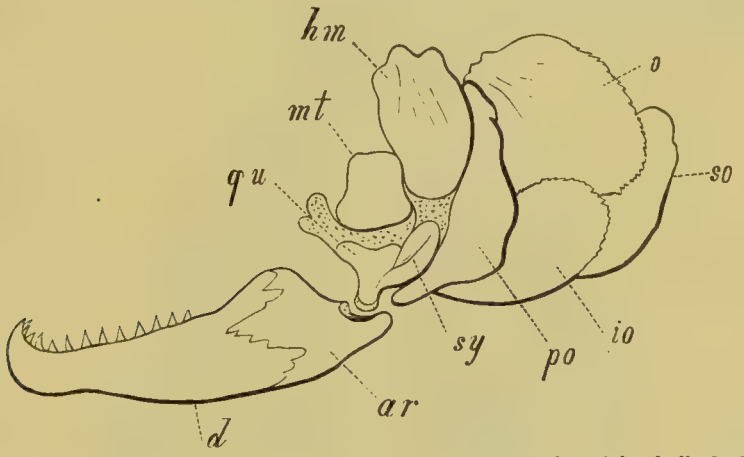


Fig. 823.—Left lateral view of the suspensorial and mandibular region of the skull of a Salmon. *hm*, Hyomandibular; *mt*, Metapterygoid; *qu*, Quadrate; *sy*, Symplectic; *po*, Preopercular; *io*, Interopercular; *so*, Subopercular; *o*, Opercular; *ar*, Articular; *d*, Dentary. (After Parker.)

and the skull becomes more or less completely covered in with a series of ossifications developed in the membrane overlying the brain, while the cartilaginous foundation itself is likewise converted into bone. Bones derived from these two totally distinct sources amalgamate in the adult in such a manner as to afford no clue to their dual origins. Following a modification of an arrangement adopted by Professor Weinsheimer, the more important bones of the cranium may be enumerated as follows: the relative position of most of them being shown in figs. 824 and 825.[1] The cartilage bones comprise the *basioccipital*, *basisphenoid*, and *presphenoid*, which are median ossifications (not shown in the two figures) lying in this order (from the posterior extremity) on the inferior aspect of the cranium, and the first forming the floor of the *foramen magnum*, or aperture by which the spinal cord enters the cranium, and the three being collectively known as the *basi-cranial axis*. On

[1] In the sequel the figures of the skulls of many reptiles, and more especially those of *Ichthyosaurus* and *Nothosaurus*, show the general relations of the bones of the skull to advantage.

the sides of the basioccipital we have the two *exoccipitals*, forming the lateral boundaries of the foramen magnum, and either alone or in conjunction with the basioccipital, the single or double *occipital condyles*, by which in the higher forms the cranium articulates with the atlas vertebra. The bony auditory capsule is composed typically of the *proötic*, *epiotic*, and *opisthotic*,[1] to which in Teleostean Fishes must be added the *sphenotic* and *pterotic*; but, as will be noticed below, some of these bones may unite, when they receive a distinct name. The *alisphenoids* and *orbitosphenoids* are paired bones developed in the trabecular region; while the single *ethmoid* and the paired *turbinals* occur in the nasal region. The position of the *quadrate* has been already mentioned. Among investing or

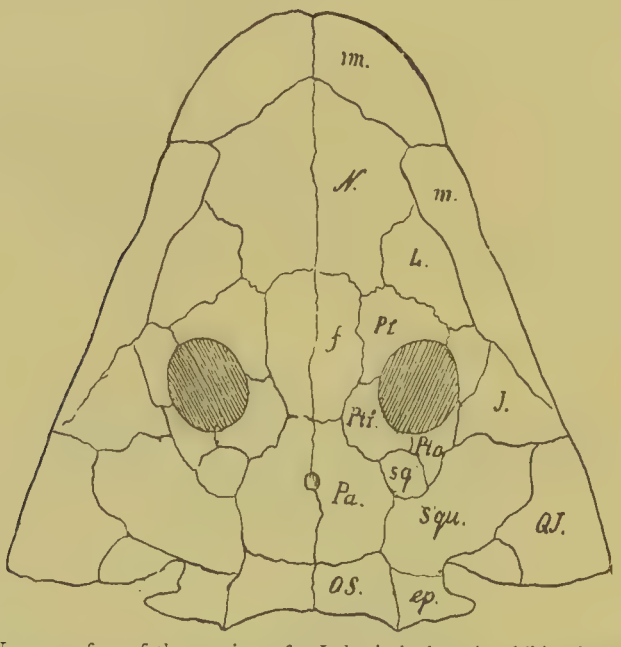


Fig. 824.—Upper surface of the cranium of a Labyrinthodont Amphibian (*Xyrania*), one-half natural size. *im*, Premaxilla; *m*, Maxilla; *N*, Nasal; *L*, Lachrymal; *f*, Frontal; *Pf*, Prefrontal; *J*, Jugal; *QJ*, Quadratojugal; *ep*, Opisthotic; *OS*, Supraoccipital; *Sq*, Squamosal; *Squ*, Supratemporal; *Pa*, Parietal; *Ptf*, Postfrontal; *Pto*, Postorbital. The quadrate would come below *QJ*; the large vacuities are the orbits; and the small aperture in *Pa* the parietal foramen. (After Fritsch.)

membrane bones, which are of a more or less splint-like structure, we have the following paired ossifications, reckoning from before backwards, on the upper surface—viz., *premaxilla* (*im*), *maxilla* (*m*), *nasal* (*N*), *lachrymal* (*L*), *frontal* (*f*), *prefrontal* (*Pf*), *postfrontal* (*Ptf*), *postorbital* (*Pto*), *parietal* (*Pa*), *supratemporal* (*Squ*), and *squamosal* (*Sq*). In some Dinosaurian Reptiles, as *Stegosaurus*, there appears to be a distinct bone above the orbit, which connects the pre- and postfrontal, and may be termed the supraorbital. The

[1] Shown in the skull of *Testudo*, figured in the sequel, fig. 1017 A.

supraoccipital (*OS*), which, although double in the figured skull, is usually a single bone, appears to be developed inferiorly from cartilage and superiorly from membrane; it usually forms the upper border of the foramen magnum, and is not unfrequently produced posteriorly into a long spine. On the lateral aspect of the cranium are placed the *jugal* (*J*), and *quadratojugal* (*QJ*), which connect the quadrate with the maxilla; while inferiorly (fig. 825) we may have a median splint-like *parasphenoid* (*Ps*), and always a single or

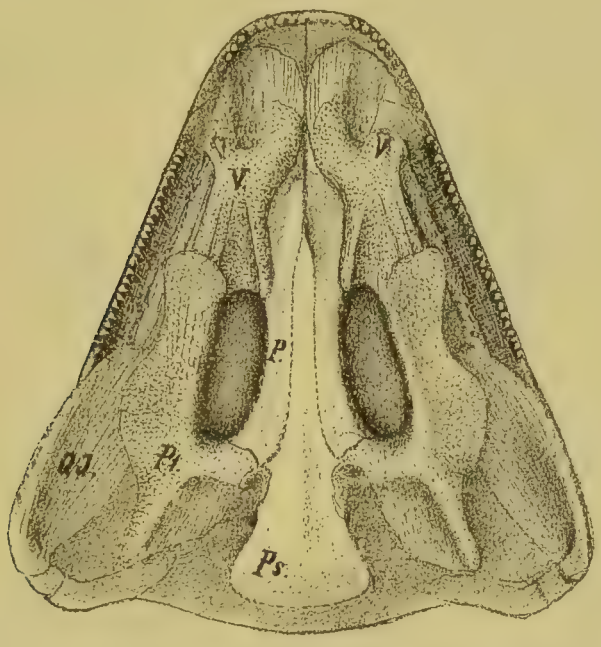


Fig. 825.—Under or palatal view of the cranium represented in fig. 824. *V*, Vomer; *P*, Palatine; *Pt*, Pterygoid; *QJ*, Quadratojugal; *Ps*, Parasphenoid. (After Fritsch.)

paired *vomer* (*V*), and the paired pterygoids (*Pt*), and palatines (*P*). The two latter, it may be observed, are developed upon the primitive palatopterygoid bar; while the parasphenoid, when present, underlies the basicranial axis, and if largely developed, as in Teleostean fishes and Amphibia (fig. 825), seems to take the place of the basi- and presphenoid.

In the cranium of which an upper view is given in fig. 824 the whole of the region behind the orbits is completely roofed over by bone, so that a secondary roof is thus formed above the roof of the much smaller brain-case which lies within. In most Reptiles there are, however, vacuities or fossæ in this outer roof (as in fig. 826), although in the Turtles and the Ichthyosaurs (fig. 1024) this roof persists. In fig. 826 the upper-lateral vacuity is termed the *supratemporal fossa*, and is bounded below by the *superior temporal* (or

squamoso-prefrontal) *arcade* formed by the squamosal, postorbital, and postfrontal; while the lower or *infratemporal fossa* is bounded superiorly by the last-named arcade, and below by an *inferior temporal* (or *quadrato-maxillary*) *arcade*, formed in most Reptiles (fig. 826) by the quadrate, quadratojugal, jugal, and maxilla. In the Mammalia (where it is usually termed the *zygomatic arch*) we find, however, a single arcade formed by the squamosal, jugal, and maxilla, and a similar arcade, but with the apparent absence of the jugal, occurs in many of the Anomodont Reptiles. This may be termed the *squamoso-maxillary arcade*. In many Sauropsida, when a postorbital or postfrontal is developed, these two arcades are



Fig. 826.—Right lateral aspect of the cranium of *Sphenodon punctatus*. The lower vacuity on the left is the infratemporal fossa, bounded below by the inferior, and above by the superior temporal arcade; the vacuity above the latter being the supratemporal fossa. The posterior border of the latter fossa is formed by the parieto-squamosal bar. The quadrate is on the left lower corner of the figure. (After Günther.)

usually connected behind the orbit by a process from the former articulating with another from the jugal, and thus forming a bar or arch which may be termed the *postorbital bar* or arch. Similarly another bar at the posterior extremity of the supratemporal fossa is formed by the quadratojugal (or quadrate), squamosal (the supratemporal of fig. 824 being absent), and parietal, and may be termed the *posttemporal*, or *parieto-squamosal bar*, or arch. A third fossa behind this bar is termed the *posttemporal fossa*. It will be observed that these numerous vacuities expose to view the brain-case lying within these arches or bars; and there seems to have been a gradual tendency to open up the completely roofed skull of the Labyrinthodont Amphibia till in the Mammals we find, as already mentioned, the squamoso-maxillary, or zygomatic arcade, and often a postorbital bar, as the sole remnants of this primitive secondary roof.

It will not be necessary to mention the various neural and vascular foramina of the cranium, but it must be observed that on the upper aspect there are paired apertures for the *orbits* (fig. 826), and either paired or single ones for the *nares* (*ibid.*); while between these apertures there may be the paired *preorbital vacuities*, which are shown

in the figure of the skull of *Phytosaurus* among the Crocodilia. Mention must also be made of the *parietal foramen* (fig. 824), which is a vacuity occurring in the parietals of many Reptiles and Amphibians. In several living forms this foramen immediately overlies an aborted median eye embedded in the subjacent tissues, and totally functionless; but it is not improbable that in the Labyrinthodonts and other early forms this eye served the purposes of vision. As the attention of the palæontologist is often directed to them, we must also observe that the *Eustachian tubes* are canals connecting the internal ear with the pharynx or gullet. Apart from certain minor ossifications which will be incidentally noticed in the sequel, we must also call attention to the *periotic* and *tympanic* of Mammals, since among the Cetacea these bones are of great importance to the palæontologist. Both these bones are connected with the internal ear, the first resulting from the coalescence of the proötic, epiotic, and opisthotic of the lower forms, and containing the *cochlea* of the ear; while the latter is formed by ossification in the tissues around the tympanic membrane, and also occurs in some Birds. Finally, the term *tympanic ring* is a convenient one to apply to the bones surrounding the external ear of Reptiles, and especially the Chelonia.

In regard to the *mandible*, or lower jaw, which we have already stated to be formed by ossifications in the region of Meckel's cartilage, each half, or *ramus* (fig. 827), in the Sauropsida and Am-

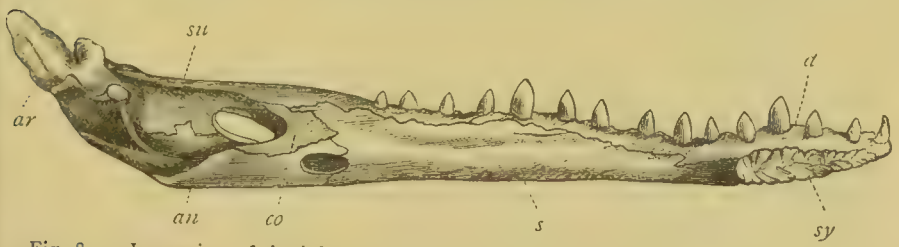


Fig. 827.—Inner view of the left ramus of the mandible of *Crocodilus*. *sy*, Symphysis; *d*, Dentary; *s*, Splenial; *co*, Coronoid; *an*, Angular; *su*, Surangular; *ar*, Articular. Reduced. (After Cuvier.)

phibia consists of the following five ossifications formed in membrane—viz., *dentary* (*d*), *splenial* (*s*), *coronoid* (*co*), *angular* (*an*), and *surangular* (*su*). These unite with the *articular* (*ar*), formed from Meckel's cartilage, which articulates by a *glenoid cavity* with the quadrate. In Mammals, however, there is but a single membranous ossification in each ramus, which posteriorly articulates by a rounded *condyle* with the squamosal bone of the cranium, there being apparently no articular ossification, and no distinct quadrate in connection with the mandible.[1] In the Sauropsida the quadrate articulates

[1] See the introductory chapter on the Mammalia (Chapter lvii.)

directly with the periotic region; but in the greater number of Fishes the mandible, as already mentioned, is connected with the cranium by means of the hyomandibular suspensorium (fig. 823).

Having now noticed the leading features of the axial, we may proceed to an equally brief survey of those of the appendicular skeleton. In all the higher Vertebrates the limbs are divided into three sections — viz., in the *pectoral* or fore *limb* the *arm*, *fore-arm*, and the *hand* or *manus*; and in the *pelvic* or hinder *limb* the *thigh*, *leg*, and the *foot* or *pes*. The first segment has a single bone—the *humerus* of the arm, and the *femur* of the thigh (fig. 828); the second has two parallel bones—the *radius* and *ulna* in the fore-arm, and the *tibia* and *fibula* in the leg (fig. 828); while the third segment contains a number of bones arranged in not more than five longitudinal rows (figs. 828, 829), with the exception of the Ichthyopterygian Reptiles. The bones of the manus and pes are again divisible into three sections—viz., proximally the *carpus* or wrist in the manus (fig. 829), and the *tarsus* or ancle in the pes; mesially the *metapodium*, or *metacarpus* of the manus (fig. 829), and the *metatarsus* of the pes (fig. 828); and distally the phalangeals (figs. 828, 829) of the digits. With the exception of the Ichthyopterygia, where the normal digits appear to have divided, in all known forms the number of functional digits does not exceed five; and these are enumerated consecutively from the radial or tibial side, so that the *pollex* or thumb of the manus, and the *hallux* or great toe of the pes are always termed the first, and the little finger and toe the fifth digits. Except in the hallux there are usually not less than three phalangeals in each digit of the pes, but their number may be reduced in the manus. The bones of the metapodium correspond in number with the digits, and consist of a single transverse row.

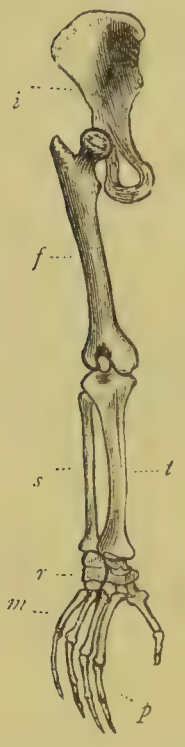


Fig. 828. — Dorsal aspect of right innominate and pelvic limb of the Chimpanzee (*Troglodytes*), reduced. *i*, Innominate; *f*, Femur; *t*, Tibia; *s*, Fibula; *r*, Tarsus; *m*, Metatarsus; *p*, Phalangeals. (After Owen.)

Although, as we have stated, the number of digits in the higher Vertebrates is typically five, yet there appears to be considerable evidence that the number was originally seven. Thus in many pentedactylate Mammals, and also in some Reptiles and Amphibians, there is found on the radial or preaxial border of the carpus or tarsus a small ossification which Dr Bardeleben terms the *prepollex*, or *prehallux*, and regards as

the representative of an additional radial digit. Similarly the *pisiform* bone of the carpus, which occurs on the ulnar or postaxial border, and in Mammals is usually described as one of the so-called sesamoid bones, is looked upon by the same authority as the representative of a seventh digit on the ulnar side.

It is probable that the carpus and tarsus were originally formed upon a common type, which persists in a more or less unaltered condition in certain Amphibia and Reptilia (fig. 829). In such a generalised type there is a distal row of five carpalia (fig. 829), or tarsalia, articulating with the metapodials. This is preceded proximally by another row, consisting of an *intermedium*, flanked in the manus by a *radiale* and *ulnare*, and in the pes by a *tibiale* and *fibulare*, respectively articulating with the two epipodial bones of the fore-arm (radius and ulna) or leg (tibia and fibula). The middle space between these two transverse rows of bones is occupied by one *centrale*, or occasionally by several *centralia*. Modifications from this type are caused by the suppression or coalescence of some of these elements. All the carpals and tarsals in the Mammalia have received distinct names, which will be noticed under the head of that class; but it may be observed here that the higher Reptiles and Birds agree with the former in having two bones in the proximal row of the tarsus —viz., the *calcaneum* on the fibular, and the *astragalus* on the tibial side.

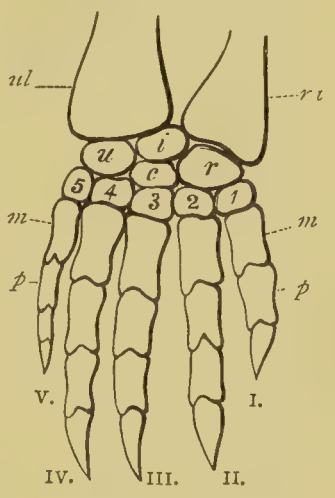


Fig. 829.—Dorsal aspect of the right manus of a Chelonian Reptile (*Chelydra*). *ra*, Radius; *ul*, Ulna; *r*, *i*, *u*, Radiale, ulnare, and intermedium; *c*, Centrale; 1—5, Carpalia; *m*, Metacarpals; *p*, Proximal phalangeals; 1.—v., Terminal do., 1. being the pollex. (After Gegenbaur.)

The protuberances for muscular attachment at the proximal extremity of the humerus are termed *tuberosities*, while those of the femur are known as *trochanters*. The latter bone in the Sauropsida may also have an *inner trochanter* on its shaft for the attachment of the *femoro-caudal* muscle; while in the Mammalia there may be a *third trochanter* for that of the gluteus maximus, as is shown in the femur of *Rhinoceros* represented in fig. 1226. Both the humerus and femur have more or less distinct *condyles* at the lower extremity for the articulation of the bones of the fore-arm and leg—those of the humerus being often termed *trochleæ*. Above the condyles or trochleæ the humerus has projecting *epicondyles* on either side; and there is frequently a foramen situated above either

the outer or inner epicondyle. When placed above the outer or radial epicondyle this foramen is termed *ectepicondylar*, and when above the inner or ulnar epicondyle *entepicondylar*. The proximal extremity of the ulna is often produced into an *olecranon* (fig. 1300), which projects behind the end of the humerus. The distal extremity of the tibia in certain Sauropsida develops from its anterior aspect a ridge or process known as the *cnemial crest;* while the *deltoid crest* or ridge is a prominence situated below the head of the humerus on the radial side, to which the attention of the palæontologist is not unfrequently directed. Finally, the *patella* is a so-called sesamoid bone developed in the tendon of a muscle passing over the pulley-like surface or trochlea on the anterior aspect of the distal extremity of the femur.

Since the limbs of Fishes differ considerably from the higher type of structure noticed above, their consideration may be deferred till we come to that class. Before, however, leaving the subject of limbs, it should be observed that it is often convenient to allude to the corresponding or homologous sides of the fore and hind limbs by a single term. If, then, we imagine the limbs extended more or less nearly at right angles to the axis of the body (as on the left side of fig. 814), with the palm of the hand and the sole of the foot directed to the front or ventral aspect, the middle digit of each limb will be *axial*, when the pollex and radius of the pectoral, and the homologous hallux and tibia of the pelvic limb, will be obviously *preaxial;* while the fifth digit of each limb, together with the ulna and the fibula, will be *postaxial*. The whole of the radial and tibial sides of the limbs will accordingly be known as the *preaxial*, and the ulnar and fibular as the *postaxial border*.

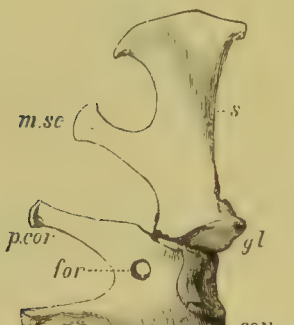


Fig. 830.—Lateral aspect of the cartilage bones of the left side of the pectoral girdle of a Lizard (*Iguana*). *s*, Scapula; *m.sc*, Mesoscapular process of do.; *cor*, Coracoid; *p.cor*, Precoracoidal process of do.; *m.cor*, Mesocoracoidal process of do.; *for*, Foramen of do.; *gl*, Glenoid cavity.

The remaining parts of the skeleton comprise the *pectoral* and *pelvic girdles*, by which the corresponding limbs are respectively connected with the trunk, and of which the relative positions are shown in fig. 818. The pectoral arch is never connected by means of ribs with the vertebræ, and primitively consists of three main bones developed in cartilage. On the dorsal aspect of the body we have the upper bone or *scapula* (fig. 830, *s*); while on the ventral side there are two parallel bones (fig. 974), the anterior of which is termed

the *precoracoid* (*cl*), and the posterior the *coracoid* (*co*). At the junction of these three bones there is a cavity for the articulation of the head of the humerus termed the *glenoid cavity*. Such is the primitive condition of this girdle; but in Reptiles the precoracoid very rarely exists as a separate ossification, although it does so among the Anomodonts, where, at least in the young, it forms a large plate, uniting below to the upper edge of the coracoid, and entering into the formation of the glenoid cavity.[1] In all other cases it is, however, completely fused either with the scapula or the coracoid. Thus in the Chelonia (fig. 1008) the precoracoid retains its primitive form and condition of a transverse bar, which is, however, completely fused with the scapula. In the Lizards, on the other hand, this bone has united with the coracoid, of which it forms the precoracoidal process (fig. 830, *p.cor*)—the foramen (*for*) marking the original line of separation between the two bones. In Dinosaurs and many other Reptiles the precoracoidal process has disappeared, and only the foramen remains; while in the Ichthyopterygia even this is wanting. A further reduction occurs in the higher Mammals, where the whole of the coracoid has disappeared as a distinct bone. The coracoid is subject to great variation in shape, and may either simply meet its fellow by an overlapping or sutural junction, or may articulate with the sternum.

A *clavicle*, mainly developed from membrane, may be connected with the preaxial borders of the scapula and coracoid; while a mesial T-shaped *interclavicle* (fig. 819), which is also developed from membrane, may receive the inner extremities of the two clavicles, and then usually overlies the upper part of the sternum. Finally, there may also be a single or double mesial *omosternum* developed on the ventral aspect from cartilage lying near the anterior extremity of the girdle. An illustration of the position of this bone is shown in the pectoral girdle of the Frog, represented in fig. 974.

In the pelvic girdle we have three separate ossifications arising in cartilage, of which all three usually unite to form an *acetabulum* (fig. 831,[2] *a*, *b*) for the reception of the head of the femur, or thigh-bone. The bone commonly known as the haunch-bone forms the dorsal element, and is technically termed the *ilium* (*ibid.*, *Il*); it corresponds to the scapula, and usually articulates with the sacrum by short ribs; while in the ventral half we have anteriorly the *pubis* (*ibid.*, *P*), representing the precoracoid; and posteriorly the *ischium* (*ibid.*, *Is*), which corresponds to the coracoid. The two latter bones

[1] This precoracoid appears to correspond with the bone termed *epicoracoid* by Professor Cope, and also the one so named in the Monotreme Mammals.

[2] Here the acetabulum is formed by only two bones, and it has been suggested that the bone lettered pubis may be really an epipubis.

very generally meet those of the opposite side in a ventral symphysis; and when, as is frequently the case, the three bones of either side are anchylosed together, an *innominate* bone results (fig. 1128 *bis*). The ischium and pubis of the same side may also unite inferiorly so as to enclose the *obturator notch*, *F*, which then forms the *obturator foramen* (fig. 1128 *bis*); while an *obturator process* of the ischium may form a smaller foramen below the acetabulum, as in the pelvis of *Camptosaurus*, figured in the sequel (fig. 1052). As a rule, there is no tendency to a reduction in the number of the pelvic bones in the higher forms. It may be mentioned, in conclusion, that a median ossification at the ventral symphysis of the pubis and ischium found in certain *Edentates* has been named the *pelvisternum*, and regarded as the abdominal representative of the sternum. This appears, however, to correspond with the median ossification found in the Ungulates (fig. 1128 *bis*), which is generally looked upon merely as an epiphysis. The pectoral and pelvic girdles of Fishes are noticed in the next chapter.

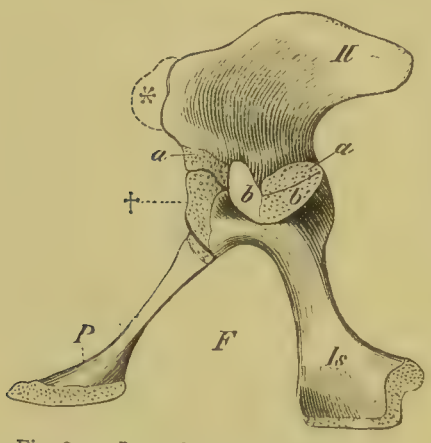


Fig. 831.—Lateral aspect of the left half of the pelvis of a young Crocodilian (*Alligator*). *Il*, Ilium; *P*, Pubis; *Is*, Ischium; *F*, Obturator notch; *a*, *b*, *b*, Acetabulum, with its vacuity; †, *, Cartilaginous extensions of ilium.

It may be well to observe here that genera being purely and simply artificial divisions formed for the convenience of classification, it is quite unnecessary that they should be of equivalent value in different groups of animals. As examples of vertebrate groups in which generic terms are used in a wide sense, we may cite the Reptilan order Sauropterygia and the Mammalian family *Rhinocerotidæ*; while as instances where a more restricted application is employed, we may mention the order Chelonia, and the family *Bovidæ*. The statement we not unfrequently hear that such-and-such a form *must* represent a distinct genus implies a total misconception of the import of generic terms.

CHAPTER XLVI.

CLASS PISCES.

General Structure.

The members of the class Pisces, commonly known as Fishes, form the first division of Professor Huxley's Ichthyopsida, and are generally characterised by living in water; breathing by branchiæ, or gills, throughout life; having the heart furnished with a single ventricle and auricle (atrium); having the limbs, when present, in the form of fins; being provided with unpaired median fins supported by fin-rays; and by the skin being either naked, or covered with dermal scales or bony scutes. There is no amnion or allantois developed in the embryo, and the reproduction is nearly always oviparous. Certain forms do not, however, exhibit all the above features, and the relation of the more generalised Fishes to the Amphibia is very intimate. The peculiar system of mucous canals and the lateral line are highly characteristic of Fishes, although they are not invariably present.

Before noticing such features as are of especial importance to the palæontologist, it will be convenient to mention that according to the arrangement adopted in this work the class is divided into the following six orders—viz., Cyclostomi, Elasmobranchei, Chimeroidei, Dipnoi, Ganoidei, and Teleostei, of which the salient features will be noticed in the succeeding chapter. Dr Günther has, indeed, proposed to bracket together the second, third, fourth, and fifth orders as a subclass under the name of Palæichthyes, ranking as equivalent to the Cyclostomi and Teleostei. Professor Huxley, Dr Traquair, and others have, however, shown that the Ganoidei are so intimately connected with the Teleostei, while the Elasmobranchei, Chimeroidei, and Dipnoi differ in so many respects among themselves and from the former, that such a grouping does not appear consonant with their true relationship.

Another scheme, proposed by Professor Cope and adopted by

Mr Smith-Woodward, is to brigade the Teleostei and Ganoidei together in a subclass under the name of Teleotomi, with ordinal divisions differing somewhat from the subordinal ones employed below, and to raise the Dipnoi, Chimeroidei, Elasmobranchei, and Cyclostomi to the rank of subclasses, with the concomitant elevation of their respective suborders to the rank of orders. It seems, however, scarcely to harmonise with the divisions adopted in the other classes of Vertebrates to regard a group like the Chimeroidei as a subclass, and accordingly the view of Professor Huxley is provisionally followed of regarding the Elasmobranchei and Chimeroidei as divisions of ordinal value.

Although the body in all Fishes must be adapted for progression through the water, yet there is an enormous range of variation in its contour among the different groups, as we may observe when we contrast a Lamprey, a Shark, a Flat-fish, a Ribbon-fish, and a Globe-fish. The dermal structures termed scales, which are so characteristic of Fishes, present many types of structure. In the Teleostei they usually form thin plates, frequently marked by concentric lines and not formed of true bone.

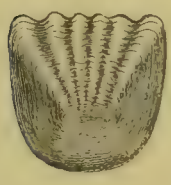


Fig. 832.—Cycloid scale, enlarged.



Fig. 833.—Ctenoid scale, enlarged.

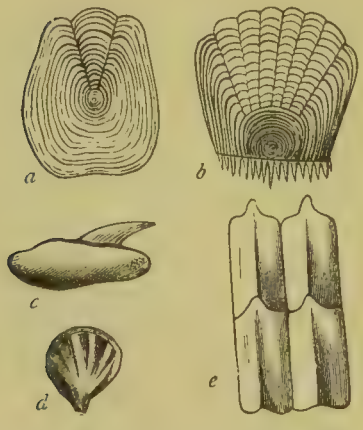


Fig. 834.—*a*, Cycloid scale of Pike (*Esox*); *b*, Ctenoid scale of Perch (*Perca*); *c*, Dermal plate of Thornback (*Raia*); *d*, Do. of Monkfish (*Squatina*); *e*, Ganoid scales of *Palæoniscus*. *a* and *b* enlarged.

When the posterior margin is simple (or entire) such a scale is termed *cycloid* (fig. 832), but when denticulated, *ctenoid* (fig. 833). Other examples of this type are shown in figs. 834, *a*, *b*. In many Ganoids and a few Teleosteans the scales are much thicker, and consist of a variety of true bone covered externally with an enamel-like substance termed *ganoine*. Such scales, of which specimens are shown in fig. 834, *e*, and fig. 835, are termed *ganoid*; they are arranged in oblique rows, and connected together by a peg-like projection, their shape being oblong. Scales of ganoid structure may, however, be much thinner, and resemble the cycloid type in their contour and their imbrication. Lastly, the bony dermal scutes or plates, frequently armed with a spine, which occur in the skin of the Sharks and Rays (fig. 834, *c*, *d*), are strictly comparable in structure to teeth, consisting of

a cap of enamel underlain by dentine and supported on bone. Allied to these are the calcified scutes of the Coffer-fishes (*Ostracion*), File-fishes (*Balistes*), and Sturgeons (*Acipenser*), to all of which structures the term *placoid scales* was formerly applied. A characteristic feature in the Teleostei is the presence of a series of perforated scales running along the side of the body, known as the *lateral line*, the canal of this line being apparently in part connected with the supply of mucus, and acting partly as a sense-organ. The modified scales of this line may be larger or smaller than those of the rest of the body, or may be the only ones present. A lateral line is also found in some Ganoids and in certain Elasmobranchs, as well as in the Chimeroids. A series of large V-shaped scales found on the borders of the fins of many Ganoids are termed *fulcra*. The dermal fin-rays are peculiar to the present class, and are shown in figs. 836, 837. They



Fig. 835.—Ganoid scale.

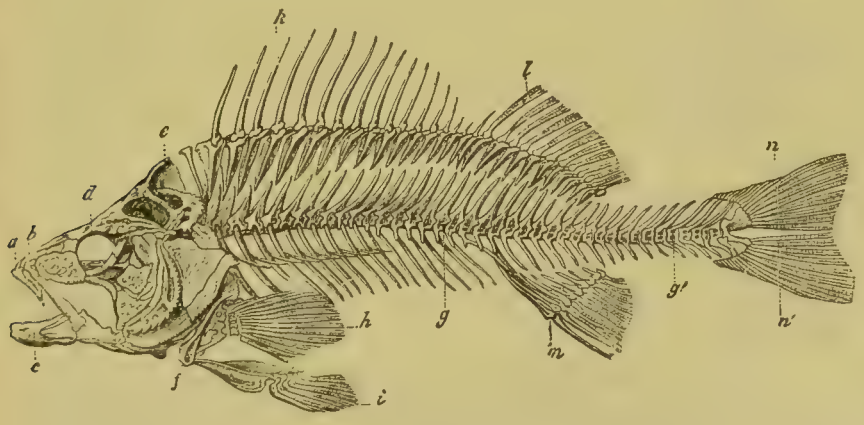


Fig. 836.—Reduced left lateral view of the skeleton of the Perch (*Perca*). *a*, Premaxilla; *b*, Maxilla; *c*, Mandible; *d*, Orbit; *e*, Supraoccipital; *f*, Preoperculum; *g*, *g'*, Vertebræ; *h*, Pectoral fin; *i*, Pelvic do.; *k*, *l*, First and second dorsal do.; *m*, Anal do.; *n*, *n'*, Caudal do. The bones between *k* and *l* and the vertebræ are the interspinals.

occur both in the paired *pectoral* and *pelvic* fins, and also in the median *dorsal*, *caudal*, and *anal* fins. In Elasmobranchs these fin-rays are horny; but in the Teleostei (fig. 836) they are bony, and generally split up into filaments at the extremities (*l*), although they may be pointed (*k*). In Teleostei they generally consist of two closely applied parts, diverging at the base to articulate in the median fins with the interspinous bones of the endoskeleton, and in the paired fins with the distal limb bones. In Elasmobranchs the interspinals are represented by the so-called radial cartilages belonging to the true endoskeleton.

In Teleosteans and Ganoids the anterior rays of the dorsal and

pectoral fins may be developed into huge dermal spines, which in some cases articulate by a complete shackle-joint with the basal bones. Similar spines are also developed in the Elasmobranchei

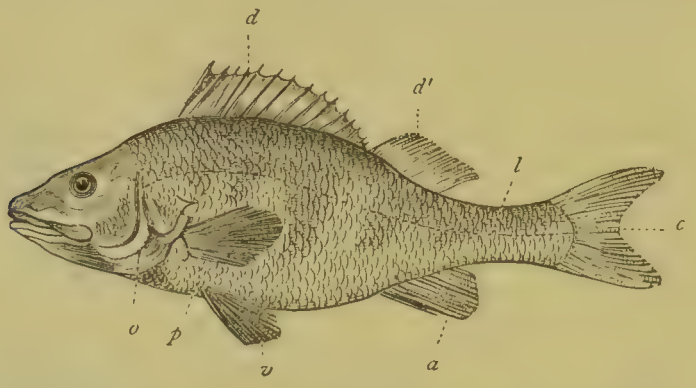


Fig. 837.—Left lateral view of the Perch (*Perca*). *o*, Gill-cover, with gill-slit behind it; *p*, Pectoral fin; *v*, Pelvic do.; *d*, First dorsal do.; *d'*, Second dorsal do.; *l*, Lateral line. Reduced.

(fig. 838); but here they are simply inserted into the flesh, or are attached only by cartilage, so that their basal end is rounded off. Similar spines (fig. 838, 1) may also occur behind the head. Such

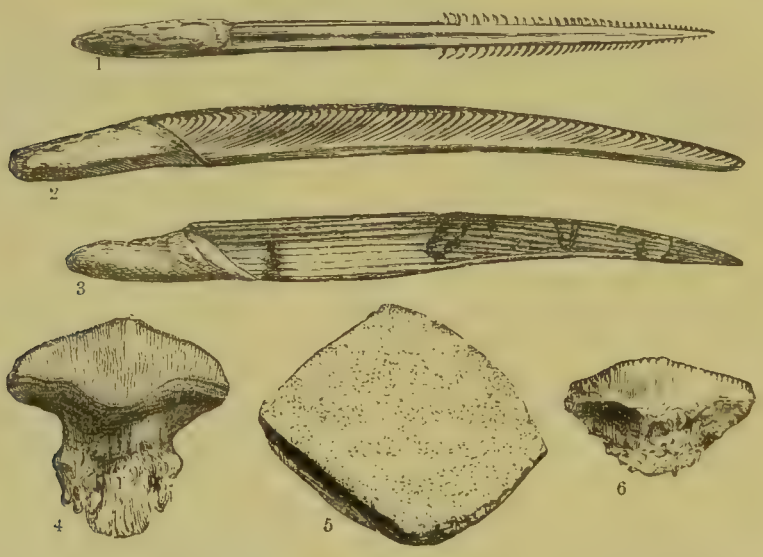


Fig. 838.—Spikes and teeth of Elasmobranchei. 1, Nuchal spine of *Pleuracanthus*; 2, Fin-spine of *Gyracanthus*; 3, Do. of *Ctenacanthus*; 4, Tooth of *Petalodus*; 5, Do. of *Psammodus*; 6, Do. of *Ctenoptychius*. Carboniferous. 1–3 are reduced.

spines when found fossil are frequently known as *ichthyodorulites*, and form important objects to the palæontologist. Their structure is identical with that of the so-called placoid scales and of teeth,

there being a central pulp-cavity, surrounded by a layer of dentine or vasodentine, which is covered with enamel.

The teeth of Fishes present a greater amount of variation than is found in any other class. They may be entirely absent, or may be present on all the bones of the mouth, and also on the hyoids and branchial arches, while they may be attached merely to the membrane of the mouth-cavity. Very frequently they are attached by anchylosis to the underlying bone or cartilage (fig. 838), but they may be implanted in distinct sockets or alveoli. The dentine is usually distinguished from that of the teeth of higher Vertebrates by its greater vascularity. The coating of enamel is generally very thin; but it is more developed in the cutting-teeth of *Sargus*. Occasionally (*Dendrodus*) radiating prolongations of the pulp-cavity may penetrate the dentine from the centre to the periphery, thus producing a structure like that of the teeth of the Labyrinthodont Amphibians. There is generally a constant renewal of the teeth of Fishes during the whole of life; but occasionally one set persists.

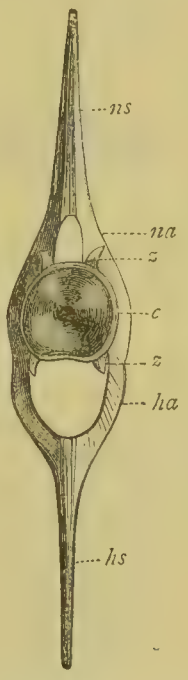


Fig. 839.—Anterior aspect of a caudal vertebra of a Teleostean Fish *ns*, Neural spine; *na*, Neural arch; *z*, Articular processes; *ha*, Hæmal arch; *hs*, Hæmal spine. (After Günther.)

Turning to the endoskeleton, and commencing with the vertebral column, we find that the vertebræ can only be divided into a trunk and a caudal series, and that there is a gradual progression in respect of ossification from the lowest to the highest forms. Thus, in the Cyclostomi, the notochord persists throughout life, and is generally unsegmented, although rudimental neural arches and spines are developed in *Petromyzon*. The vertebral column of the Cartilaginous Ganoids is very similar to that of the latter; but in Bony Ganoids, Elasmobranchei, and Teleostei paired cartilages, arising both above and below the notochord, gradually surround it, and thus form strongly amphicœlous vertebral centra. In the Sharks these centra exist without arches, but in the other orders there are well-developed neural arches; and in the trunk region there are also lateral *basal processes*, which in the tail unite inferiorly to form a hæmal arch for the caudal artery, and develop a hæmal spine (fig. 839). There is a great tendency for the neural arches to remain open superiorly; and the only Fish in which the vertebræ are not amphicœlous is the Ganoid *Lepidosteus*, in which they are opisthocœlous. Only in the Chimeroidei and certain Elasmobranchei are there definite articulations between the vertebral

column and the cranium; the posterior aspect of the basioccipital in other groups forming a cup like that of a vertebral centrum. The mode in which the vertebral column terminates posteriorly is of considerable importance in classification. The most primitive

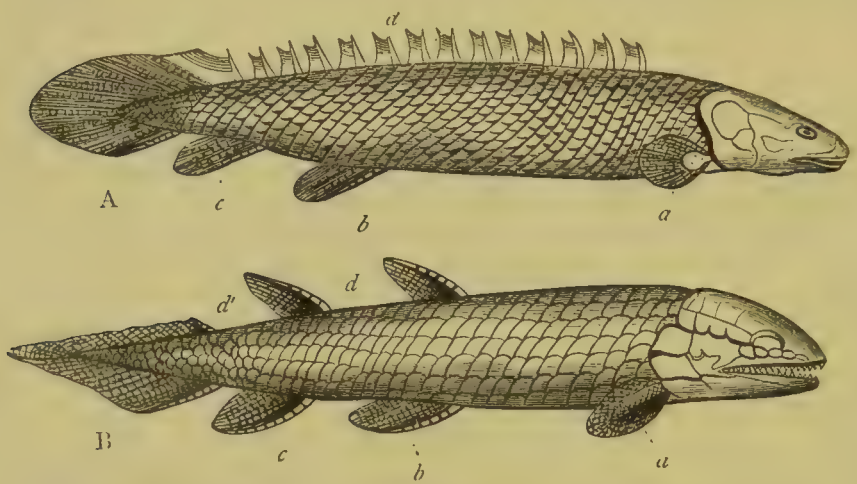


Fig. 840.—A, *Polypterus*, and B, *Osteolepis* (Ganoids), to show diphycercal caudal fin. *a*, Pectoral; *b*, Ventral; *c*, anal; *d*, Dorsal fin. Reduced.

type occurs in the Cyclostomi, Dipnoi, and many Ganoids, where the notochord continues to the extremity of the body, and is symmetrically surrounded by the caudal fin, as in fig. 840; this type is known as *diphycercal*. In the other, or *heterocercal* type, the notochord

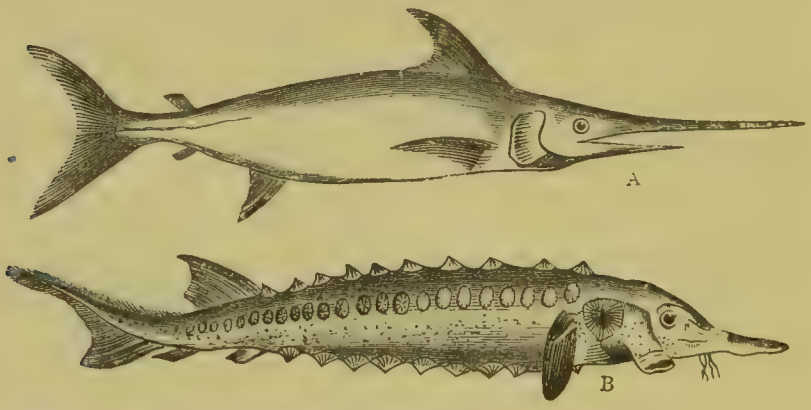


Fig. 841.—A, Sword-fish; B, Sturgeon, to show masked (homocercal) and typical heterocercal tail.

is bent upwards, owing to the greater development of the lower as compared to the upper half of the tail. This feature may be observable externally, as in the Sturgeons (fig. 841, B) and Sharks; or may be masked, as in the majority of Teleostean Fishes (fig. 841, A), by the symmetrical arrangement of the fin-rays. The skeleton (fig.

842) shows, however, the upward bend of the notochord, although this is very much less marked in the adult than in the young. This masked heterocercal type is sometimes described as *homocercal*. The coalesced hæmal spines found in this type of tail are known as *hypural* bones (fig. 842, *h*), while the ossified extremity of the notochord is termed the *urostyle*.

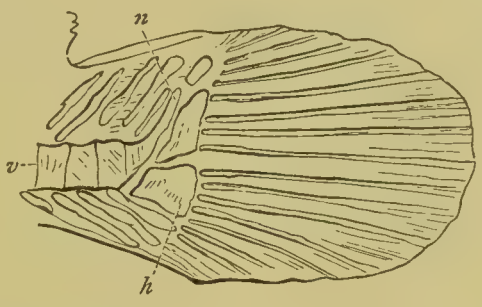


Fig. 842.—Tail of Flounder. (After Agassiz.) *v*, Vertebral column; *n*, Turned-up end of the notochord; *h*, Hypural bones.

The skulls of Fishes present variations in regard to their degree of ossification, analogous to those obtaining in the vertebral column. The general structure of the primitive cartilaginous skull has been already indicated in Chapter xlv. (fig. 822), but we must here glance briefly at certain bones developed in the more specialised forms which are peculiar to the class. Thus, taking as an example the skull of a Teleostean Fish (fig. 843), where the primitive cranium is concealed by the development of investing bones, we find two peculiar ossifications in the auditory region known as the pterotic (*ibid.*, *Pte*), which is considered to represent the squamosal and opisthotic of higher Vertebrates, and the sphenotic (*ibid.*, *Sph*). A large parasphenoid is always present inferiorly (fig. 844). The intervention of the hyomandibular and symplectic (figs. 823 and 843) between the quadrate and the squamosal region has been already mentioned in Chapter xlv. as peculiar to Fishes (although it is by no means universal in the class); and we must also mention that, in addition to the normal palatine and pterygoid bones developed

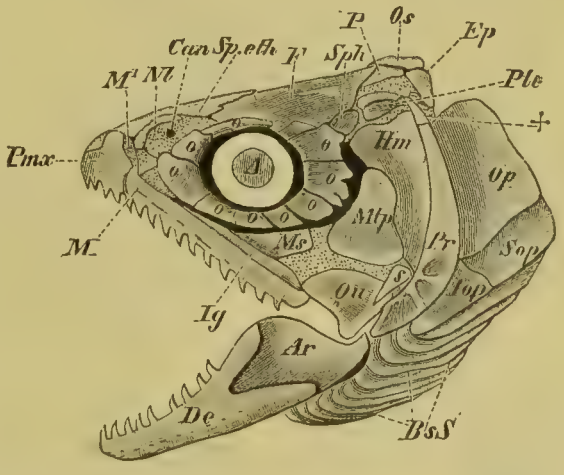


Fig. 843.—Left lateral view of the skull of a Trout (*Salmo*). *Ep*, Epiotic; *Pte*, Pterotic; *Sph*, Sphenotic; *Os*, Supra-occipital; *P*, Parietal; *F*, Frontal; *Sp.eth*, Ethmoid; *Can*, Aperture of olfactory nerve; *Nl*, Nasal; *Pmx*, Premaxilla; *M*, *M*¹, Maxilla; *Ig*, Jugal; *Ms*, Mesopterygoid; *Mtp*, Metapterygoid; *o*, *o*, Suborbitals; *Hm*, Hyomandibular; *s*, Symplectic; *Qu*, Quadrate; *Pr*, *Iop*, *Sop*, Pre-, inter-, and subopercula; *Op*, Operculum; *BsS*, Branchiostegal rays; *Ar*, Articular; *De*, Dentary; *A*, eye. (After Wiedersheim.)

round the cartilaginous palatopterygoid bar, there occur in Teleostei the *meso-* and *metapterygoid* (fig. 843, *Ms*, *Mtp*). In the same class the orbital region likewise develops a series of membrane-bones round the eye, forming the *suborbitals* or *orbital ring* (*ibid.*, *o*, *o*), while the *gill-cover* or *operculum* (of which the first trace is found in the Chimæroids in a fold from the hyomandibular overlapping the first gill-slit) is formed by the *preopercular*, *opercular*, *subopercular*, and *infraopercular* (*ibid.*, *Pr*, *Op*, *Sop*, *Iop*), which are broad, scale-like membrane bones. In the *branchiostegal membrane*, which unites with the gill-cover in closing the branchial chamber, there is developed a number of *branchiostegal rays* (fig. 843, *BsS*, and fig. 844, *bo*); but these may be partly or entirely replaced by

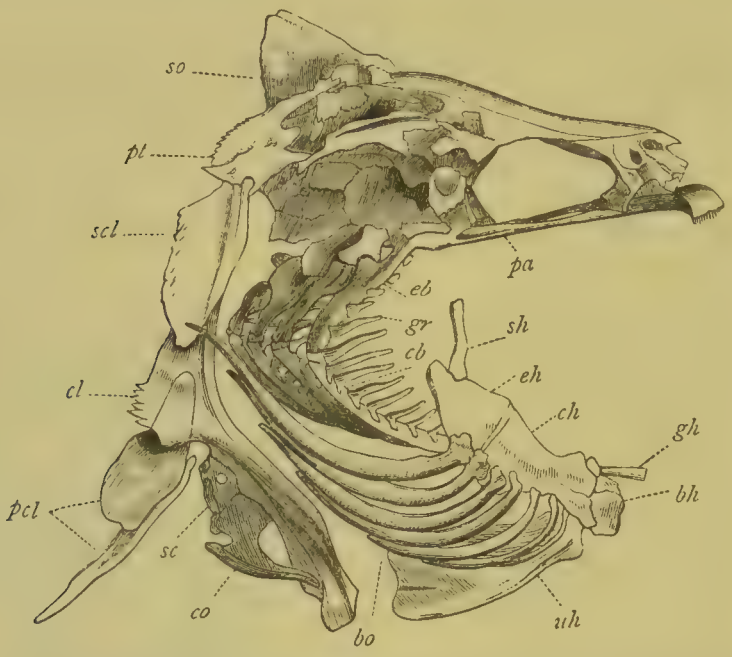


Fig. 844.—Right side of the cranium proper of a Perch, together with the hyoid and branchial arches, and the pelvic girdle. *sh*, Stylohyal; *eh*, Epihyal; *ch*, Ceratohyal; *bh*, Basihyal; *gh*, Glossohyal; *uh*, Urohyal; *bo*, Branchiostegal rays; *cb*, Ceratobranchial; *eb*, Epibranchial; *gr*, One of the "gill-rakers" of the first branchial arch; *pa*, Parasphenoid; *so*, Supraoccipital; *pt*, Posttemporal; *scl*, Supraclavicular; *cl*, Clavicular; *pcl*, The two pieces of the postclavicular; *sc*, Scapula; *co*, Coracoid.

jugular plates, occupying the space between the rami of the mandible. The hyoid arch (fig. 844) is attached to the inner side of the hyomandibular by a *stylohyal* (*ibid.*, *sh*), articulating inferiorly with the *epihyal* (*eh*), and the latter with the large *ceratohyal* (*ch*); the two latter carrying the branchiostegals. The inferior part of this arch is formed by the *basihyal* (*bh*), from which the *glossohyal* (*gh*) extends forwards into the tongue, and posteriorly articulates with the first of the *basibranchials*, mentioned below. The *urohyal*

(*uh*) is a vertically-compressed median bone, extending backwards from the basihyals. Behind the hyoid arch occur the *branchial arches*, the first of which consists of a median *basibranchial*, and laterally from below upwards of a *hypobranchial*, *ceratobranchial* (fig. 844, *cb*), *epibranchial* (*eb*), and *pharyngobranchial*. The latter bones in the second and third arches are called *superior pharyngeals*, and generally carry teeth. Finally, the *gill-rakers* (fig. 844, *gr*) are spine-like bones attached to the inner margins of the branchial arches.

In the mandible there is usually (fig. 843) a dentary and articular piece; but an angular, and more rarely a splenial or coronoid, may also be present.

In the appendicular skeleton, we find the pectoral girdle of Ganoids and Teleosteans consisting inferiorly of the primary cartilaginous elements corresponding to the scapula and coracoid (fig. 844, *sc*, *co*), and superiorly and laterally of a secondary chain of bones developed from membrane, and articulating superiorly with the pterotic region of the skull. The bones of this secondary chain are named from above downwards *posttemporal* (fig. 844, *pt*), *supraclavicular* (*scl*), *clavicular* (*cl*), and a *postclavicular* of two pieces (*pcl*); while there may be also an *infraclavicular* below the clavicular. In Elasmobranchei only the cartilaginous primitive girdle is developed; while in Dipnoi the girdle is of very peculiar structure, and somewhat intermediate between that of Elasmobranchei and Teleostei. The pelvic girdle is generally wanting; but in the Dipnoi there is a median cartilaginous plate, with anterior and posterior paired processes, of which the former are iliac, and the latter give attachment to the hind limbs. Elasmobranchs generally show a degenerate pelvis of this type.

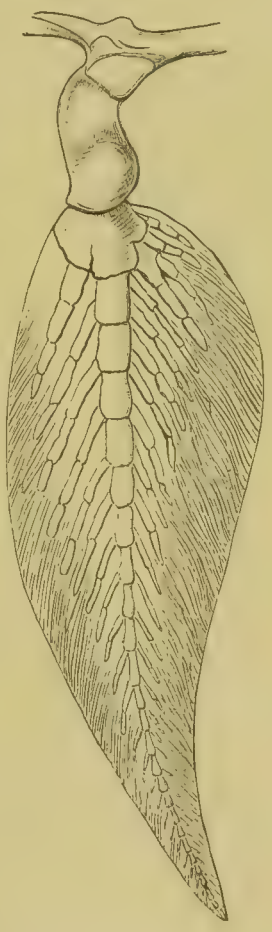


Fig. 845.—Skeleton of the left pectoral limb of *Ceratodus*. Reduced. (After Günther.)

The pectoral and pelvic limbs, or fins, are so similar in structure that they may be considered together, although the development of the latter is less specialised than that of the former. No representatives of the arm and fore-arm of the higher Vertebrates can be detected in Fishes, the basal and radial bones or cartilages articulating directly with the pectoral

girdle. In the Dipnoi, and especially in *Ceratodus*, the pectoral (fig. 845) and pelvic fins are supported by a cartilaginous, median, segmented axis, bearing jointed radii on the dorsal and ventral borders—these radial cartilages being terminated by horny dermal fin-rays; and the dorsal radii (left side of figure) being more numerous than the ventral. This type of fin, which also occurs in the Ichthyotomous Elasmobranchei, is known as the *archipterygium*. From this slightly unsymmetrical type of fin that of existing Selachian Elasmobranchs (fig. 846) may be derived by the gradual suppression of the ventral series of rays, and the development of the dorsal, which has now become lateral. Basally the jointed radial cartilages articulate proximally with the *pro-*, *meso-*, and *metapterygium*, which in their turn are attached to the pectoral arch, and the latter of which corresponds to the basal axial cartilage of the fin of *Ceratodus* (fig. 845). In the pelvic fin of the Selachians the mesopterygium is absent, and the propterygium more or less rudimentary. This type of fin is known as the *ichthyopterygium*. The fins of Ganoids and Teleosteans may be derived from the Selachian type; but the primary cartilaginous skeleton is reduced, and a secondary one developed by the introduction of membrane bones.

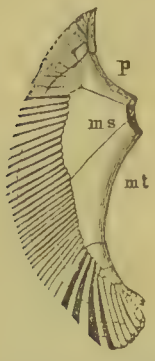


Fig. 846.—Skeleton of the left pectoral limb of the Monkfish (*Squatina*). *p*, Pro-; *ms*, Meso-; *mt*, Metapterygium. Much reduced.

Before leaving the structure of Fishes, mention must be made of the *otoliths*, which are small, rounded, elliptical bodies, usually with one convex and one concave side, lying in the tympanic sac, and composed of both calcic carbonate and phosphate. These bodies have been carefully studied by Dr Koken, and several genera identified by their evidence in a fossil state.

As regards their distribution in time, Fishes being the lowest class of the Vertebrata, it would naturally be supposed that they were the earliest representatives; and this appears to have been the case. The earliest known fishes in Britain belong to the Ganoid group *Placodermata*, and occur in the Lower Ludlow group of the Silurian; while the Elasmobranchei were represented in the topmost group of the same series. In the Devonian and Carboniferous periods Fishes become abundant; but all the forms from these horizons, and up to the Cretaceous, belong to the Elasmobranchei, Chimæroidei, Dipnoi, and Ganoidei—the specialised Teleostei not making their appearance, so far as we know with certainty at present, till the Cretaceous. The Ganoids of the suborder Amioidea approximate, however, so closely to the Teleostei, that it has been a question whether some of the members of the Jurassic family *Lepto-*

lepididæ, which are usually placed in the former, should not be transferred to the latter group; and we may thus confidently expect to find a complete transition between the two. Although many of the Cretaceous Teleostei are more or less closely allied to existing types, it is not until the Eocene that we find a fish-fauna comparable to that of the present day; and we may note that the resemblance of the fishes of the Eocene to those now living is in marked contrast to what obtains in Mammals, where the majority of Eocene genera are extinct. The persistence of some genera of Fishes throughout long geological epochs is indeed a noteworthy circumstance, and is nowhere more marked than in the case of *Ceratodus*, which has lived on continuously from the Triassic period of Europe, and also from that of certain North American beds, which are usually referred to the Permian.

In regard to the origin of the various orders of Fishes, it is pretty evident that the Teleostei were derived from the Ganoidei, and that the Dipnoi were closely related to one branch of the latter. The

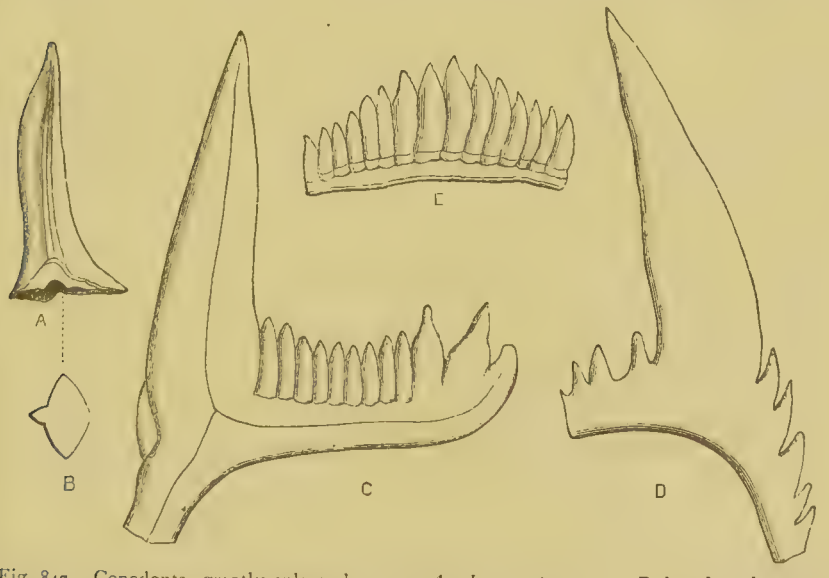


Fig. 847.—Conodonts, greatly enlarged. A, B, *Acodus acutus*; C, D, *Prionodus elegans*; E, An unnamed form; A–D, From the Silurian of Russia; E, From the Carboniferous of North America. (After Pander and Newberry.)

phylogenetic relationship of the Ganoids to the Elasmobrancheans is, however, still unsettled, although recent researches tend to show a close connection between the more primitive and least specialised groups of the two orders. Palæontology has not, indeed, yet taught us from what group of animals these primitive Ganoids and Elasmobranchs were themselves derived. It has, however, been suggested by Professor Cope that the Placodermoid Ganoids were closely re-

lated to the Ascidian Invertebrates; and if this suggestion should prove well founded, it would seem to indicate that the group mentioned is closely allied to the real ancestors of the class. Possibly, however, these ancestors are to be sought in another direction, since it has been thought that minute tooth-like bodies found in beds ranging from the Upper Cambrian to the Carboniferous, and known as *Conodonts* (fig. 847), are really the teeth of Fishes. It was considered probable at one time that these curious fossils, which rarely exceed two millimetres in length, might be teeth of extinct members of the Cyclostomi; but their internal structure is so different from the teeth of the existing forms of that order, that if they belong to Fishes at all, they must apparently indicate an extinct division. A great variety of forms of these Conodonts have been described, and have received distinct generic and specific names. It is the opinion of some authorities whose judgment is entitled to great consideration that these fossils should be regarded as the jaws of Annelids[1] or Trilobites; but the question as to their real nature must be regarded as still undecided.

[1] *Vide supra*, vol. i. p. 480.

CHAPTER XLVII.

CLASS PISCES—*continued.*

Orders Cyclostomi and Elasmobranchei.

Order I. Cyclostomi. — The Cyclostomi, which include the Hag-fishes (*Myxine* and *Bdellostoma*) and Lampreys (*Petromyzon*) being at present unknown in a fossil state, require no further notice in the present work.

Order II. Elasmobranchei.—This order, which is also known under the name of Chondropterygii, includes a peculiar extinct group termed the Ichthyotomi, together with the modern Sharks, Dog-fishes, Saw-fishes, and Rays, collectively constituting the Selachii, and all of which are typically of marine habits. For palæontological purposes this order may be characterised as follows: The skeleton is invariably cartilaginous, and membrane bones are, with some possible exceptions, absent in the skull; the vertebral column is, however, generally divided into distinct segments, of which the centra may be marked by a calcification differing in structure from true bone. In the skull, which may be either movably or immovably connected with the vertebral column, the palatopterygoid bar and hyomandibular suspensorium are never fused with the cranium. When an exoskeleton is developed, it consists of small dermal granules, of which the structure is the same as that of teeth. In all existing forms the optic nerves simply cross one another, without any interlacing of their component fibres; the bulbus arteriosus of the heart has three series of valves; the intestine is furnished with a spiral valve; and the ova are of large size and few in number.

A few words may be said explanatory of some of the above-mentioned and other features in existing forms before proceeding to the systematic part. In all forms, as already mentioned, there is a separate suspensorial arrangement articulating with the cranium, to which the mandible is attached; this structure being termed *hyostylic*. Usually there is a hyomandibular suspensorium intervening

between the cranium and the palatopterygoid bar; but in *Notidanus* (fig. 861) the hyomandibular element takes no share in the support of the mandible, and the palatopterygoid articulates directly with the cranium; this probably being the primitive type. The gills (fig. 848) are attached to the skin by their margins; while they usually communicate with the exterior by five apertures, or clefts, which may be very rarely increased to six or seven. The mouth is very generally situated on the inferior aspect of the body (fig. 849), and is furnished with numerous teeth carried on the palatopterygoid bar and Meckel's cartilage (fig. 861). These teeth may be either sharp and separate, or articulated together so as to form a more or less pavement-like structure; and in the former case there is a continuous succession of new teeth developed from behind as the old ones are worn out. Both median and paired fins are present; the position of the pelvic pair being always abdominal. In all existing forms the skeleton of the limbs forms an *ichthyopterygium* (fig. 846); but in the Carboniferous and Permian Ichthyotomi there is either a uniserial or biserial *archipterygium*, like that of the Dipnoi. The posterior termination of the vertebral column is generally heterocercal, with the upper lobe of the caudal fin greatly elon-

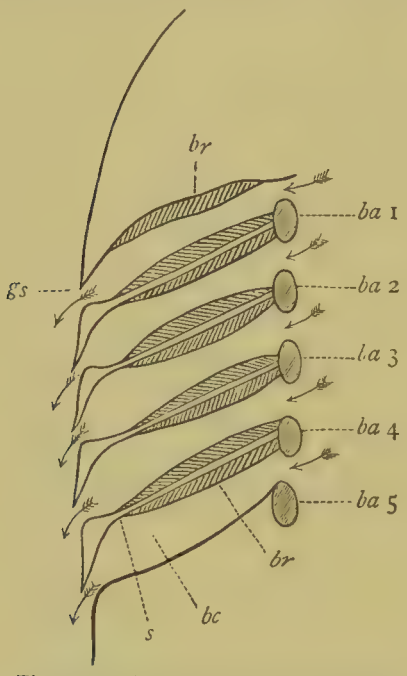


Fig. 848.—Diagram of one side of the gills and gill-pouches in a Selachian; the arrows indicating the direction of the currents. *ba* 1–5, Branchial arches transversely divided; *bc*, Branchial pouches; *gs*, External gill-slits; *s*, Septa between pouches; *br*, Branchiæ.

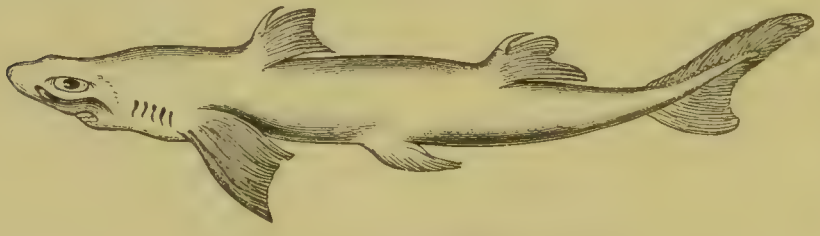


Fig. 849.—Spiny Dog-fish (*Acanthias*). Reduced.

gated (fig. 849). The spines frequently borne by the dorsal fins and in the nuchal region, constituting the so-called ichthyodorulites, have their bases simply embedded in the flesh, and are consequently immovable. There is no swim-bladder. The term *spiracles* is ap-

plied to apertures connected with respiration found on the upper aspect of the head; while the *intercalary cartilages* are ovoid or diamond-shaped structures occurring between the neural arches of the vertebræ.

Mr Smith-Woodward observes that a gradual advance in the degree of calcification of the axial skeleton may be observed as we trace the members of the order from the Palæozoic upwards, the oldest forms not having the notochord differentiated into distinct vertebral centra, of which we find the first complete types in the Lower Liassic *Palæospinax*. Here, however, the centra merely assume the form of double cones, only very slight traces of the peripheral calcifications necessary to form the biconcave centra of the later types being visible. In the Lower Kimeridgian lithographic stone of the Continent, centra of the complete *asterospondylic* type are first met with.

The same authority mentions that the Palæozic types are, as a rule, characterised by the great development of the exoskeleton, although a few forms like *Pleuracanthus* appear to have had naked bodies. These early dermal structures are also noticeable for their elaborate sculpture, this being equally developed on the dermal granules (shagreen), and on the fin and cephalic spines. Smooth fin-spines appear to be very rare in the Palæozoic, and it is not till we reach the Upper Trias and Lias that spines completely covered with smooth ganoine are met with.

In regard to the teeth, Mr Woodward observes that "pointed teeth and obtuse teeth occur among the earliest Elasmobranchs; but the former as well as the latter are firmly articulated together, and must always have formed part of a dentition in which several series were functional. Though the teeth of *Cladodus* and *Diplodus* [*Pleuracanthus*] are as sharply pointed as those of most recent Sharks, the piercing crown is placed upon a broad horizontally-expanded base, permitting of a considerable amount of interlocking between one tooth and another—an arrangement most nearly paralleled in the surviving *Chlamydoselache*. It is evident, indeed, that all the modern types of dentition, in which not more than one or two series of teeth are simultaneously functional, are highly specialised modifications of this primitive arrangement; and the change results from the deepening and lateral compression of the root of each tooth, rendering its base of support less fixed, and often not permitting its coming into use until after attaining the summit or passing the outer side of the jaw-cartilage.

"With regard to the disposition of the teeth in the mouth as a whole, the modern Rays—most *Scylliidæ* and *Chlamydoselache*—may be looked upon as retaining the most primitive arrangement. In the predaceous Sharks there has been a tendency towards the relative enlargement of the prehensile teeth upon the symphysis; while

in the Cestraciont Sharks the symphysial teeth have become small though prehensile, and the lateral teeth well adapted for trituration. The former arrangement is particularly characteristic of modern times; the latter, it is interesting to note, attained its maximum of specialisation so long ago as the Carboniferous period. In many early Carboniferous genera the series of lateral crushing-teeth began in part to fuse into continuous plates (*Pleuroplax*); two of these plates often amalgamated (*Pœcilodus*); and in the most specialised of these Cochliodonts (*e.g.*, *Deltoptychius*), all traces of the boundaries of the original components of the dental plates became obliterated."

Suborder 1. Ichthyotomi.—This name was proposed by Professor Cope for a group of primitive Elasmobranchs, ranging from the Devonian to the Permian, but perhaps also surviving to the Trias, and showing the following characteristic features. The endoskeleton has granular calcifications extending equally throughout the cartilage; the notochord in most, or all, cases is not constricted to form distinct vertebræ; and the calcification of its sheath in the precaudal region does not extend beyond that very incomplete stage to which the term *rhachitomous* has been applied—the explanation of which is given below under the head of the Labyrinthodont Amphibians. The neural and hæmal spines of the vertebræ are long and slender, and no intercalary cartilages are developed. Finally, the pectoral fins have a long segmented axis of the archipterygial type (fig. 850).

It may be mentioned here that Dr Koken is indisposed to admit the right of the Ichthyotomi to form a group of equal rank, with that embracing all other Elasmobranchs; since he regards the primitive features exhibited by the vertebral column, and the nature of the caudal fin, as only one degree removed from those found in certain Selachii. This writer, indeed, regards the *Pleuracanthidæ* and *Cladodontidæ* as so closely allied to the *Notidanidæ* and *Cestraciontidæ* (*Hybodontidæ*) that he would class the whole of these families in a single group, for which he proposes the name *Proselachii*, and in which the *Cochliodontidæ* should perhaps also be included. So far as regards the slight importance from a classificatory point of view of the imperfect calcification of the vertebral column, Dr Koken's views are in harmony with those adopted below in the classification of the Labyrinthodont Amphibia.

Family Pleuracanthidæ.—In this family the body is slender and somewhat depressed; the mouth differs from that of all the Selachii in being terminal; while the caudal fin is diphycercal. There is a long and low continuous dorsal fin; while the pectoral fin has a biserial arrangement of rays somewhat after the fashion of *Ceratodus*. The type genus *Pleuracanthus* has received an almost bewildering number of names, of which it will suffice to mention *Diplodus*, *Orthacanthus*, *Xenacanthus*, and *Didymodus;* some of

these, as their terminations indicate, having been applied to spines, and others to teeth.

Recent discoveries have enabled us to attain to a nearly complete knowledge of the anatomy of this remarkable genus, and a restoration by M. Brongniart of one of the species is shown in the accompanying wood-cut. The skin was quite naked; the body elongate, and the snout obtuse. The teeth have a thick and depressed root, with a crown formed by two unequal corners diverging like a V, with a small denticle at the base of the two, and not unfrequently a minute flattened mammilla posteriorly. In the male the pelvic fins carry a robust "clasper." At the top of the head there was a large barbed spine (fig. 852, 1), with a double row of serrations, and, according to the restoration (fig. 850), supporting a

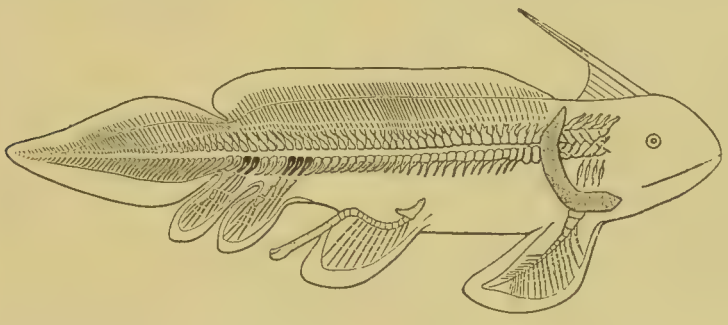


Fig. 850.—Restoration of the skeleton of *Pleuracanthus Gaudryi*; from the Carboniferous of France, reduced. (After Brongniart.)

cephalic fin. In the skull, according to Dr Koken, there was a distinct hyomandibular, but the palatopterygoid bar had a direct connection with the postorbital process of the cranium, as in *Notidanus*. Dr Koken would slightly modify the structure of the pectoral fin from that given in fig. 850. The dorsal fin is of great length, extending backwards as far as the diphycercal caudal, from which it is separated by a deep notch. According to M. Brongniart's restoration the anal fin was double, and its two divisions had a structure curiously like that of limbs; Dr Koken considers, however, that the restoration is incorrect in this particular. Specimens of the figured species attain a length of more than a yard.

In time this genus extends from the Carboniferous to the Lower Permian; while in space its range embraces both Europe and North America. *Chondrenchelys*, from the Lower Carboniferous of Dumfriesshire, which is provisionally referred to the same family, has no cephalic spine. Detached teeth from the Keuper of Somerset, described under the name of *Diplodus*, apparently indicate the survival of a form allied to *Pleuracanthus* in the Triassic period.

Family Cladodontidæ.—The second family of this suborder is too imperfectly known to admit of definition; but it appears that in the type genus the pectoral fin had only one series of rays, and was thus intermediate between that of *Pleuracanthus* and the fins of the Selachii. The type genus *Cladodus* had a broad and depressed

head, with the teeth arranged in numerous rows. The crowns of these teeth present some resemblance to those of the Selachian *Hybodus* (fig. 865); consisting of one large cone, flanked on either side by one or more smaller cones, of which the outermost is generally the largest. This genus is exclusively Carboniferous, and occurs both in Europe and North America; a large number of species being known. *Dicentrodus*, of the Scottish Carboniferous, is distinguished by the teeth having only a single lateral cone developed on one side. *Phœbodus*, of the Devonian of Iowa, is an allied genus, with the lateral cones of the teeth at least as large as the middle cone; while in *Lambdodus*, of the North American Palæozoic, these lateral cones are totally wanting. In *Dicrenodus*, of the Carboniferous of both Europe and North America, we have a modification of the Cladodont tooth, in which the central cone is compressed, with the cutting-edges serrated; while the lateral cones may either be two in number, or absent. Finally, the North American Palæozoic genus *Hypocladodus* differs from the preceding by the absence of serrations on the edges of the central cone; the lateral cones being invariably absent.

Suborder 2. Selachii.—The existing Sharks, Rays, and their allies are characterised by the endoskeleton being, as a general rule, only superficially calcified; while, except in some of the earlier forms, the notochord is constricted at the centre of each vertebra. The neural and hæmal arches of the vertebræ are short and stout; and intercalary cartilages are nearly always developed. The pectoral fin (fig. 846) has not a segmented axis, being of the ichthyopterygial type; and the axis of the pelvic fin of the male is produced into the so-called "clasper," which is connected with reproduction. Some of the other features of this suborder have been already mentioned at the commencement of this chapter. The Selachians may be divided into two sections, according to the structure of the vertebral centra. In the one the anal fin disappears, and there is a tendency to the depression of the body and the enlargement of the pectoral fins, but there is no diminution in the size of the spiracle, and the vertebræ, when fully developed, are of the type known as *tectospondylic*. In the other section the anal fin persists; the shape of the body is always rounded—not even excessively flattened in the *Scilliidæ;* the spiracle tends to abort, and may be almost or totally absent in the most specialised forms; while the fully developed vertebræ are of the type known as *asterospondylic*. The type of vertebral centra known as *cyclospondylic* occurs in the immature condition of both sections.

Section a. Tectospondyli.—In this section the vertebral centra, when fully calcified, have the concentric laminæ predominating over those that radiate from the centre. The anal fin is invariably want-

ing; while specialisation shows itself in the depression of the body and the enlargement of the pectoral fins—the spiracles being always retained. This section includes the Spiny Dog-fishes, Saw-fishes, Eagle-rays, and Rays.

Family Spinacidæ.—In this family, which includes the existing Spiny Dog-fishes (fig. 849), we have generalised forms, with the body more or less rounded, and but slightly depressed. The teeth are pointed; the pectoral fins are devoid of a notch at their root, and are not expanded anteriorly; while the gills are small and lateral, and the spiracles large. One fossil species referred to the existing Mediterranean genus *Centrina* has been recorded from the Pliocene of Italy; but this determination is not absolutely certain. *Acanthias* (fig. 849), of which two species are found at the present day in the temperate seas of both hemispheres, occurs in the Chalk of the Lebanon, and also in the Miocene of Würtemberg. Another fossil form from the Lebanon has been referred to the existing genus *Centrophorus*, but it may perhaps belong to *Acanthias*. The existing genus *Spinax* has been recorded from the Italian Pliocene. With *Scymnus* we come to another existing genus, differing from all those that precede by the absence of fin-spines. It occurs fossil in the Pliocene of Italy, which has also yielded remains referred to the allied *Echinorhinus*.

Family Petalodontidæ.—The Petalodonts form a family exclusively Carboniferous, presenting the following characters. The body was somewhat depressed, while the pectoral fins were large, and produced forwards in the direction of the head after the manner of the Rays. The teeth (figs. 851, 852) formed a close pavement in the mouth, and are compressed from before backwards, with the crown more or less bent backwards, and either blunt and obtuse, or with a cutting-edge, the root being often large. In the genus *Janassa* (*Climaxodus* or *Strigilina*), which is common to Europe and North America, the teeth (fig. 851) are so thickened and reflected, that the complete series forms an almost entirely triturating surface. These teeth are arranged in three chief rows, as in the figure, which gradually diminish in size anteriorly, and are flanked by one or more smaller rows of less thickened teeth. The body is covered with fine shagreen. The North American *Fissodus* has the margin of the crowns of the teeth cleft into two or three points; while in *Petalorhynchus*,

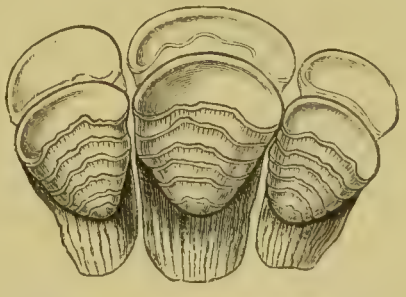


Fig. 851.—Posterior aspect of some of the central teeth of *Janassa linguæformis*; from the English Carboniferous.

which is found both in Europe and North America, the teeth are of the same general type, but have more compressed crowns, with long undivided roots. Again, in *Petalodus*, which has the same distribution as the preceding, the teeth (fig. 852, 4) are much elongated transversely, and compressed from before backwards—the crown being petal-shaped, with a smooth or slightly crenulated cutting-edge. The nature of the arrangement of the entire series is, however, unknown. The teeth of *Ctenoptychius* (fig. 852, 6) are distinguished by the coarser denticulation of their cutting-edge—those of *Callopristodus*

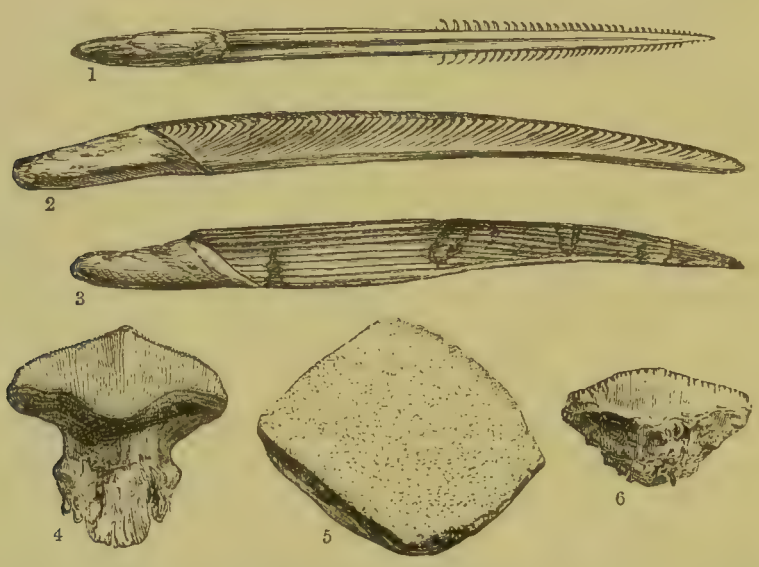


Fig. 852.—Spines and teeth of Carboniferous Elasmobranchei. 1, Nuchal spine of *Pleuracanthus lævissimus;* 2, Fin-spine of *Gyracanthus;* 3, Do. of *Sphenacanthus;* 4, Tooth of *Petalodus acuminatus*, seen from the side; 5, Do. of *Psammodus*, seen from above; 6, Do. of *Ctenoptychius*. 1–3 are reduced.

differing from the latter by the absence of enamel-folds at the base of the crown, and also by the nature of the root. It is probable that both these genera occur in North America as well as in Europe. In *Polyrhizodus* (*Dactylodus*), of both Europe and North America, the teeth are extremely stout, with low crowns, usually having a sharp cutting-edge devoid of crenulations, and a large root divided into a number of rootlets. Other allied genera from Europe are known as *Glossodus* and *Mesolophodus*.

Family Pristodontidæ.—This family is only known by the genus *Pristodus*, of the European Carboniferous, in which the crown of each tooth is thin, plate-like, and symmetrical, with hollows corresponding to elevations in the opposing tooth of the opposite jaw. It has been suggested that each jaw carried only a single tooth.

Family Squatinidæ.—With this family we come to a group represented at the present day by the Monkfish, of which the skele-

ton of the pectoral fin is shown in fig. 846 (p. 920). The body is depressed, with the mouth placed anteriorly; while the pectoral fins are much produced anteriorly, although unconnected with the head. The teeth are conical and pointed; and the dorsal fins are without spine, and placed on the tail. The only known genus is *Squatina* (*Rhina*), which ranges from the Kimeridgian upwards to the present day; although some of the fossil species have been described under other names, such as *Thaumas*. Beautifully preserved skeletons occur in the Lower Kimeridgian lithographic limestones of Bavaria, one of which is shown in the accompanying woodcut. Other species have been named from the Chalk of the Lebanon and of England, and also from the Miocene and Pliocene of the Continent; while detached teeth are found in the English Gault, the London Clay, and the Red Crag.

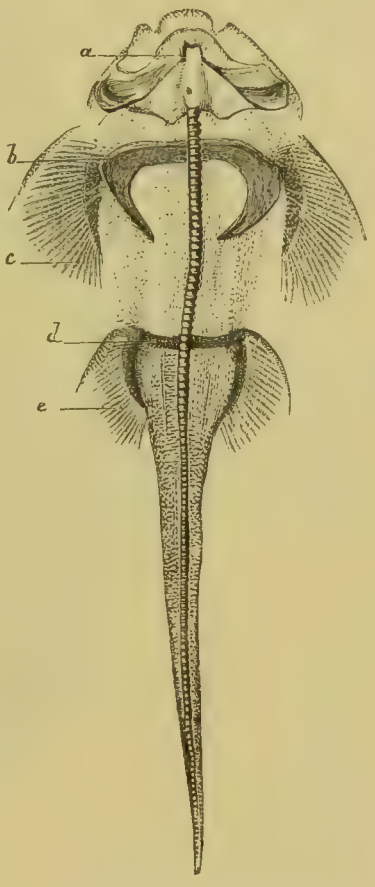


Fig. 853.—Ventral aspect of the skeleton of *Squatina speciosa*; from the Kimeridgian of Bavaria, two-thirds natural size. *a*, Mandible; *b*, Pectoral girdle; *c*, Pectoral fin; *d*, Pelvis; *e*, Pelvic fin.

Family Pristidæ.—In the true Saw-fishes the body is scarcely depressed, the pectoral fins are not much expanded, and the gill-slits are placed inferiorly. The most characteristic feature is, however, the so-called "saw," which is a long and flat calcified prolongation of the snout, armed with a series of large pointed teeth on either border. Remains of the single existing genus *Pristis* occur in the Middle Eocene of Barton and Bracklesham; in the Middle and Lower Eocene and Micoene of the Continent; and the Eocene and Upper Cretaceous of North America. *Propristis*, from the Eocene of Egypt, is said to differ by the absence of calcification in that part of the "saw" which supports the teeth; *Amblypristis*, of the same beds, has shorter and broader teeth than *Pristis*; while *Sclerorhynchus*, which may belong to the *Pristiophoridæ*, differs in the structure of the "saw," and the small size of the rostral teeth. The latter family, which has lateral gill-slits, may be represented in the Miocene of Würtemberg by a species of the existing *Pristiophorus*.

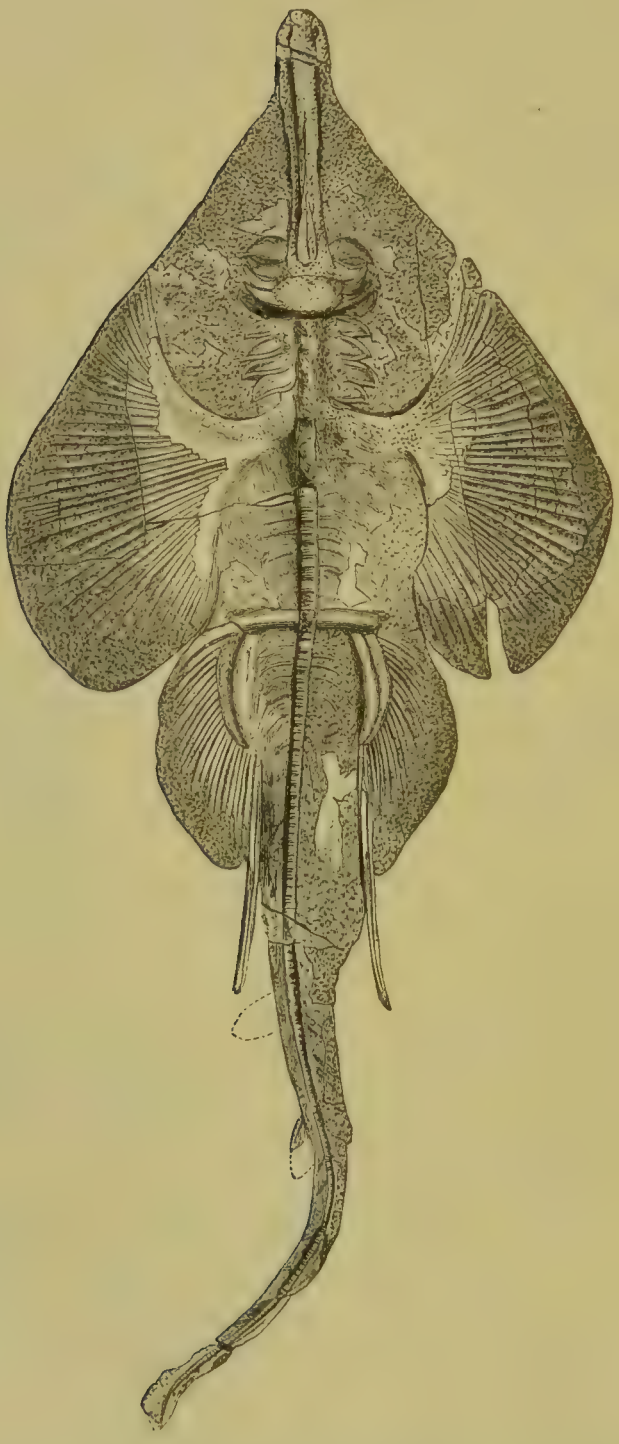


Fig. 854.—Skeleton of *Rhinobatis bugesiaca*; from the Kimeridgian of Bavaria, one-twelfth natural size. (After Zittel.)

Family Rhinobatidæ—With this family we come to Fishes to which the general term Rays may be applied; all of them are characterised by their extremely depressed bodies and the great development of the pectoral fins, so that the body proper with its fins is termed the "disk." The teeth always form a kind of pavement (figs. 856, 857). In the present family the tail is long and stout, with two well-developed dorsal fins; while there is also a caudal fin, with a longitudinal fold on either side. The disk is not excessively developed; the rayed portion of the pectoral fins not extending to the snout. The type-genus *Rhinobatis* (*Spathobatis*) is represented at the present day by about a dozen species, which inhabit the warmer seas, and attain huge dimensions. The snout is produced into a long rostrum, which is connected with the pectoral fin by a membranous expansion (fig. 854). The teeth are obtuse; and the dorsal fins are devoid of spines. In time this genus ranges from the Kimeridgian to the present day; species being recorded from the lithographic limestones of Bavaria (fig. 854) and France; from the Portlandian of France; the Chalk of the Lebanon and Italy; the Middle Eocene of Monte Bolca; the Miocene of Würtemberg; and other localities. The Australian *Trygonorhina*, which differs in the structure of the nasal valves, is said to occur in the Middle Eocene of Italy. Finally, the genera *Belemnobatis* and *Asterodermus*, respectively from the Kimeridgian of France and Bavaria, appear to connect the present with the following family.

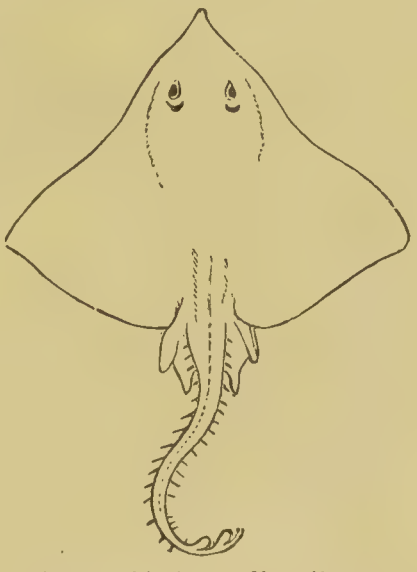


Fig. 855.—The Burton Skate (*Raia marginata*), one-sixth natural size. Recent. Britain. (After Gosse.)

Family Raiidæ.—In the true Rays or Skates (fig. 855) the disk is broad and rhomboidal, and usually has dermal rugosities; while the rayed portions of the pectoral fins extend to the comparatively short snout. The tail is also shorter than in the *Rhinobatidæ*, with a longitudinal fold; and the development of the median fin is subject to considerable variation. The type genus *Raia* (*Actinobatis*) has the tail very distinct from the body (fig. 855); the pectoral fins not reaching to the extremity of the snout; two dorsals, and either a rudimental or no caudal fin. The dentition (figs. 856, 857) often varies greatly in the two sexes; some or all of the teeth in the male being sharp, while

all those of the female are obtuse. Some of these Skates measure upwards of seven feet across the disk. In a fossil state this genus occurs in the Chalk of the Lebanon, and the Upper Eocene of Hampshire; and also in the Suffolk Crags and Italian Pliocene, where it is represented by the living *R. clavata* (figs. 856, 857). The extinct *Dynatobatis*, from the Tertiary of South America, is distinguished by the enormously expanded bases and the small spines

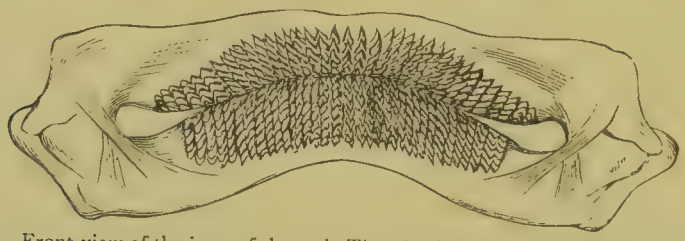


Fig. 856.—Front view of the jaws of the male Thornback Skate (*Raia clavata*). Reduced.

of the dermal tubercles with which the body is studded. *Acanthobatis*, from the Middle Miocene of France and Würtemberg, has tall dermal tubercles, with small bases, which often fuse together into

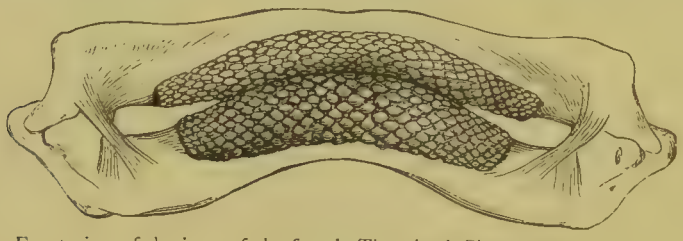


Fig. 857.—Front view of the jaws of the female Thornback Skate (*Raia clavata*). Reduced.

groups; while *Oncobatis* of the Pliocene of Idaho, which has these tubercles of a pentagonal form, may be identical with the type genus.

Family Torpedinidæ.—The Electric Rays have the disk broad and smooth; the rayed portion of the pectoral fins not continued beyond the base of the snout, and the median fins well developed. The peculiar electric organ is placed between the head and the pectoral fins. Extinct species of the existing genus *Torpedo* occur in the Middle Eocene of Monte Bolca, near Verona.

Family Psammodontidæ.—This extinct family is known only by portions of the dentition, so that its definition is at present impossible. It appears, however, from the parallelism of the mandibular rami that the body must have been depressed like that of the Rays. The teeth (fig. 852, 5) are of a flattened quadrangular form, with the root nearly as large as the crown, and were arranged in one or more longitudinal rows, which were arched antero-posteriorly with

some alternation of the teeth of adjacent rows. The genus *Copodus* has symmetrical teeth, with the postero-lateral angles of the root, and sometimes also of the crown, produced backwards; the teeth being narrowest in front, with the anterior margin usually either straight or convex. The crown surface when unworn is rugose, and marked by a more or less transverse line, which sometimes permits the two portions to be separated. This genus occurs in the Carboniferous of Europe. In the typical *Psammodus* the teeth (fig. 852, 5) are quadrangular, generally more or less oblong, but occasionally nearly square, with the root much thicker than the crown, from which it is easily separable; the surface of the crown being generally marked by transverse wrinkles. It is probable that the teeth were arranged in the jaws in four longitudinal rows. *Psammodus* is represented by a considerable number of species from the Carboniferous of both Europe and North America. Lastly, *Archæobatis*, from the Carboniferous of Indiana, is an allied form, with very large pavement-like teeth arranged in several rows, of which the under surfaces are somewhat excavated to fit the curvature of the jaws.

Family Myliobatidæ.—With the Eagle-rays we come to an existing family well represented in a fossil state as far down as the Lower Eocene; vertebræ from Cretaceous and Jurassic beds having been also referred to this family. The disk is very large, owing to the great development of the pectoral fins, which stop short at the sides of the head, but reappear at the extremity of the snout in the form of a small single or paired cephalic fin. The tail is extremely slender, and resembles a whip-lash; and the dentition, when present, forms a complete pavement. The type genus *Myliobatis* has the head free from the disk, and a single cephalic fin. The teeth are large, flat, and hexagonal, and are arranged in seven longitudinal rows; the middle row in the adult being extremely broad, while the lateral rows are lozenge-shaped (fig. 858). In the young the middle row of teeth is not larger than the lateral ones, and there is a gradual increase in the relative breadth of this row as the fish increases in age. The upper dental plate is extremely convex from before backwards, but the lower one is quite flat. In addition to the doubtful vertebræ mentioned above, this genus is known continuously from the Lower Eocene upwards, and has a wide distribution in space. Thus, in the Eocene, it is recorded from Europe, India, and

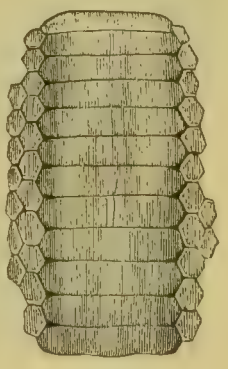


Fig. 858.—Part of the lower dental plate of *Myliobatis striata*, from the Middle Eocene of Brackle-sham, Sussex. Reduced. The second lateral rows of teeth are imperfect, and the third wanting.

North America; and it has also been described from the Tertiary of New Zealand. A very large number of specific names have been applied to the fossil forms, but Mr S. Woodward has shown that the number of valid species may be greatly reduced, since many of the characters on which they were founded are solely due to differences in the age of the specimens. In *Rhinoptera* (*Zygobates*), while the head is still free, there are two cephalic fins, and the teeth are arranged in five or more rows, of which the middle series and the adjacent pair are broad, while the one or two pairs on the borders form regular hexagons. This genus is known from the London Clay, the Eocene of South Carolina, the Swiss Miocene, and the English Crag, and is now represented by seven species from tropical and sub-tropical seas. The existing genus *Aëtobatis* is distinguished from the preceding by the teeth being arranged in only a single longitudinal row, which is often bent, and corresponds to the median row of *Myliobatis*. One species is found from the London Clay to the higher Eocene of Barton, and the genus is also represented in the Swiss Miocene. The existing genus *Ceratoptera* has no upper teeth.

In this family may be provisionally included the Cretaceous genus *Ptychodus*, which was long considered to be a Cestraciont Shark, but has been shown by Mr Smith-Woodward to be a Ray allied to *Myliobatis*. The connection between *Ptychodus* and the existing *Myliobatidæ* is shown by the genus *Apocopodon*, from the Upper Cretaceous of Brazil, which has teeth of an intermediate type; while some of the Eocene species of *Myliobatis* have teeth of nearly the same form as those of *Ptychodus*. The teeth of this genus (fig. 859) have quadrangular crowns, with the enamel of the central region thrown into a number of transverse folds, while the root is smaller and lower than the crown. The two sides of each jaw are parallel to one another, and the teeth are arranged in several parallel rows running from back to front, as is shown in the accompanying diagram (fig. 860). It will be seen, moreover, that each jaw has a single median series, composed of very small teeth in the upper, and of very large ones in the lower jaw; while on either side of this median row there is a series of teeth somewhat less large than the median row of the lower jaw. The five external rows gradually decrease in size towards the outer side of the jaws. A comparison

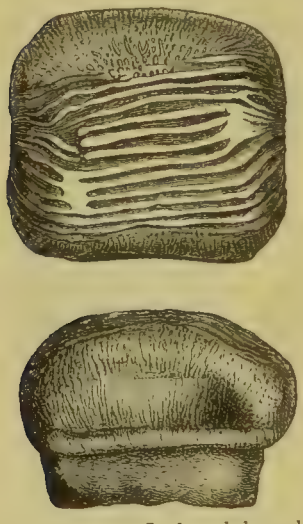


Fig. 859. — Oral and lateral views of the crown of a tooth of *Ptychodus polygyrus*, from the Upper Greensand of Regensburg. (After Zittel.)

with fig. 858 will show that the general plan of this arrangement of the teeth is essentially the same as in *Myliobatis*. This genus has a wide distribution, being found in the Upper Cretaceous of Europe, India, and North America.

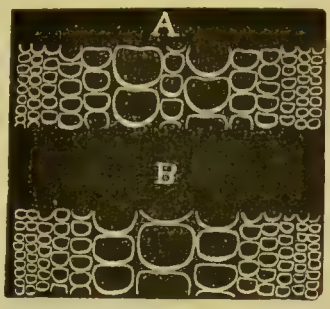


Fig. 860.—Diagram of the arrangement of the teeth in the upper (A) and lower (B) jaws of *Ptychodus decurrens*. (After S. Woodward.) Reduced.

Family Trygonidæ.—In this family the pectoral fins continue to the extremity of the muzzle, with which they are confluent. The tail is slender, and sharply distinguished from the disk; while the vertical fins are imperfect or absent, and may be replaced by serrated spines. There is some uncertainty as to the occurrence of *Trygon* in a fossil state, but it is probable that either this genus or the allied *Tæniura* date from the Middle Eocene of Monte Bolca, and remains referred to the former have been described from the Upper Cretaceous of New Zealand. The extinct *Xiphotrygon*, from the Eocene of Wyoming, is distinguished by its cuspidate teeth. Remains referable to the existing tropical genus *Urolophus* occur in the Middle Eocene of Italy, and perhaps in that of Belgium; while *Cyclobatis* is an extinct genus from the Cretaceous of the Lebanon.

Section B. Asterospondyli.—This section is distinguished from the last by having the radiating laminæ predominating over the concentric ones in the fully calcified vertebral centra, so that a section shows a star-like arrangement. The anal fin is always present; while specialisation does not tend to a flattening of the body, or to an expansion and forward growth of the pectoral fins, and the spiracles are small, and may disappear. This section comprises the true Sharks and the Dog-fishes.

All these fishes have elongated and subcylindrical bodies, and a strong tail, well adapted for swimming. The anterior, and very frequently all the teeth are formed on the type of a laterally compressed cone with trenchant edges, at the base of which two or more minor cones may be developed. In many cases, however, the hinder teeth have obtuse crowns, adapted for crushing. The two rami of the jaws are never parallel to one another, in consequence of which the teeth are always set in oblique rows (fig. 864), and never form the straight antero-posterior rows, like those occurring in the Rays (fig. 860). Sharks are carnivorous, and of active pelagic habits; and are most numerous in tropical seas, although they ascend tidal rivers, and are even found in an inland lake in the Fiji Islands.

This section may be divided into two series, in the first of which

there is but one dorsal fin, and the number of the gill-clefts exceeds five.

Family Notidanidæ.—The single family of this series is represented by the genera *Notidanus* and *Chlamydoselache*, both of which inhabit the warmer seas. The dorsal fin has no spine, and the teeth, of which several series are in use at the same time, have sharply pointed cusps. *Notidanus* (*Heptanchus*, *Hexanchus*) is readily

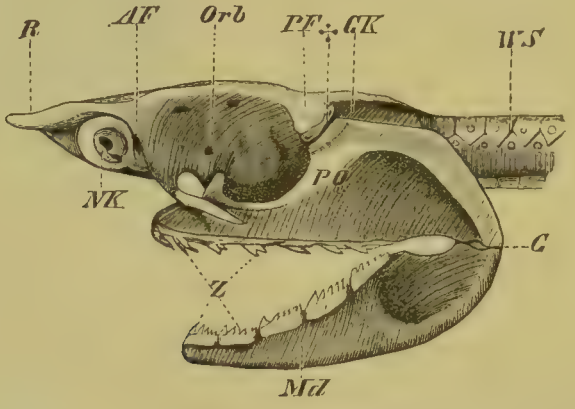


Fig. 861.—Left lateral view of the skull of *Notidanus*. Recent. Reduced. *R*, Rostrum; *AF*, *PF*, Pre- and postorbital processes; *Orb*, Orbit; *NK*, Nasal capsule; +, Articulation of palatopterygoid (*PQ*); *G*, Articulation of Meckel's cartilage (*Md*); *Z*, Teeth; *WS*, Vertebral column. (After Wiedersheim.)

characterised by the inferior position of the mouth and the peculiar form of the lateral teeth. These lateral teeth (figs. 861, 862) are comb-like, consisting of a series of compressed cones, inclined in one direction, and fixed upon an elongated base; the anterior cone being the largest, and frequently having cusps at the base of its anterior border. The lower teeth are more complex than the upper, and the anterior teeth in both jaws are simple and awl-shaped. The primitive position of this genus is shown by the persistent notochord and the characters of the skull (fig. 861). The latter approaches the so-called amphistylic type, differing from that of all other existing Selachians by the slenderness of the upper part of the hyoid arch, which does not support the palatopterygoid bar and mandible. The palatopterygoid is connected, however, with the cranium by a distinct facet articulating with the postorbital process. This structure is re-



Fig. 862.—Lower teeth of *Notidanus gigas*; from the Red Crag. The anterior cusps are worn away in the lower figure. (After Smith-Woodward.)

garded by Mr Smith-Woodward as but very slightly removed from the original primitive condition; *Cestracion*, in which the hyomandibular becomes distinctly differentiated, being a step in advance. In time this genus is definitely known to range from the Middle Jurassic of the Oxford Clay to the present day; it has indeed been recorded from the Lias, but the determination is more than doubtful. Nearly all the described species are European, but one has been recorded from the Tertiary of New Zealand. Some of the fossil teeth show signs of wear at their summits, and it thus seems that they must have been firmly implanted in the jaws like those of the Hybodonts; specialisation having apparently tended to produce a loose dental articulation throughout the section. The genus *Chlamydoselache* has a terminal mouth, with lateral teeth similar in both jaws, and consisting of three slender cones separated by smaller cusps; the notochord being partly calcified. This genus is now known by a single living species from the Japanese seas, but teeth from the Pliocene of Tuscany have been referred to it. It will be observed from the figure that the mandibular articulation of *Notidanus* is placed far behind the cranium proper, and it is noteworthy that a similar condition obtains in *Pleuracanthus* among the Ichthyotomi.

Family Cochliodontidæ.—With this family we enter the second series of the section, in which there are two dorsal fins and five gill-clefts. The present extinct family is an ill-defined one, apparently allied to the *Cestraciontidæ*, but with a more specialised dentition. The dentition is formed from that of the *Cestraciontidæ* (*infra*) by the welding of at least one of the oblique transverse rows of teeth encircling each ramus of the jaws into a continuous curved plate (fig. 863), which may have either a smooth crown-surface, or may be marked, as in the figured example, by grooves and ridges, indicating its compound origin. These dental plates grow by additions to their inner borders, while the outer borders are usually involuted. The dorsal fins were provided with spines. This family comprises a number of genera from the Carboniferous, only some of which can be very briefly noticed in this work. The one most imperfectly known is *Helodus*, from the English Carboniferous, which appears allied to the next, but does not seem to have had the teeth welded into plates, and therefore differs from the accepted definition of the family. *Pleuroplax* (*Pleurodus*) and *Psephodus* are more typical forms, the latter occurring both in Europe and North America. The dental plates of *Psephodus* form at least one series of smooth curved teeth, without coronal ridges or involution of the outer border; and there were also smaller rows of lateral teeth, as well as some prehensile teeth at the extremities of the jaws. *Sandalodus* is known by the huge dental plates, which are of an elongated trian-

gular shape, with the outer border slightly involuted, and an undulating coronal contour in the upper jaw; the genus occurring in Europe and the United States. Other genera which can be merely mentioned are *Tomodus*, *Xystrodus*, *Deltodus*, and *Pœcilodus;* the three last being common to Europe and North America. Teeth referred to *Pœcilodus*, and to the above-mentioned genus *Psephodus*, have also been described from the Carboniferous of Northern India; and the teeth from the same beds described under the name of *Helodopsis* are likewise referable to the present family. In the type genus *Cochliodus*, of Europe and the United States, there are two pairs of dental plates in the mandible (fig. 863), in which the outer border is much involuted. The posterior plate is elongated anteroposteriorly, and has its anterior and posterior borders converging outwardly, and a prominent oblique ridge, likewise narrowing in the same direction, in the middle of the crown. The anterior plate is narrow from before backwards, with a ridge on the hinder border of its crown resembling the median ridge of the larger plate. The remaining genera of this family are *Streblodus*, *Deltoptychius*, *Diplacodus*, and *Cyrtonodus*, of which the two last are doubtfully entitled to distinction; while other names have been applied to detached anterior teeth.

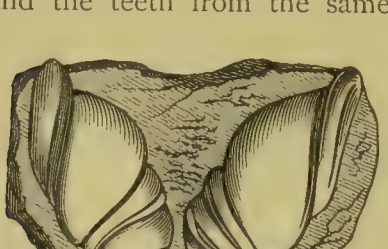


Fig. 863.—Lower dental plates of *Cochliodus contortus;* from the Carboniferous of Armagh. One-half natural size. The specimen is viewed from the anterior aspect, and the white line on the left side shows the division of the two plates.

Family Cestraciontidæ.—This family, which may be taken to include the *Orodontidæ* and *Hybodontidæ* of many writers, is represented by a considerable number of genera ranging from the Carboniferous to the present day; all the existing species being included in the type genus *Cestracion*, of which the upper dentition is shown in fig. 864. The family is characterised by the presence of a spine to each dorsal fin, of which the first is placed immediately above the interval between the pectoral and pelvic fins. The teeth are generally more or less obtuse, with several series in use at the same time, and those of each oblique series never fused into continuous plates. One of the oldest genera is *Orodus* (more correctly *Oreodus*), of the Carboniferous of Europe and the United States, in which the teeth are of the general type of those of *Hybodus*, and are only regarded by Mr S. Woodward as entitled to separation on account of the absence of other associated remains which are characteristic of the Mesozoic genus. It is probable that some of the dorsal fin-spines originally described under the name of *Ctenacanthus* belong to

Orodus. Most of these spines (fig. 852, 2) are, however, referable to the allied Carboniferous genus *Sphenacanthus;* and they are characterised by their ornamentation of robust longitudinal ridges,



Fig. 864.—Upper jaw of the Port Jackson Shark (*Cestracion Philippi*). One-half natural size. (After Owen.)

which are partly nodose. Other Carboniferous genera are *Campodus*, *Diclitodus*, and *Tristychius*, some of which have several synonyms. In the Thuringian Permian this family is represented by the genus *Wodnika*, in which the teeth have large and smooth crowns well

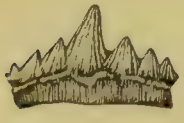


Fig. 865.—Tooth of *Hybodus raricostatus;* from the Lias of Dorsetshire. (After S. Woodward.)



Fig. 866.—Imperfect fin-spine of *Hybodus (cf) basanus;* from the Lower Cretaceous. Reduced.

adapted for crushing; while in the Muschelkalk, or Middle Trias, we have the imperfectly known *Palæobatis*, with teeth very like those of *Asteracanthus*. With the genus *Hybodus*, ranging from the Muschelkalk to the Lower Greensand of Europe, we come to a type which is now almost as well known to us as existing Sharks, owing

to the beautiful preservation of many of the specimens from the Lias, in which deposits these fishes were abundant. Many of the numerous species attained very large dimensions; and the genus may be defined by the following characters. The teeth (fig. 865) are conical or cuspidate, the crown being more or less striated, with one main cone, flanked by one or more lateral cones, and the root being more or less depressed. The teeth at the symphysis are large and few in number; while the fin-spines (fig. 866) are longitudinally grooved and ridged, with two rows of denticles placed near the posterior borders. The most remarkable feature is, however, the presence of two large hook-like spines immediately behind each orbit, which have been described under the name of *Sphenonchus*. The notochord is persistent.



Fig. 867.—Tooth of *Acrodus nobilis*, from the Lower Lias of Lyme-Regis.

Specimens of the Lower Liassic *H. Delabechei* show the whole of the dentition *in situ*; and it appears from these that there was no median symphysial row of mandibular teeth, but that there were ten transverse rows of lower teeth, with five teeth in each row, while the number of rows in the upper jaw was either nine or ten. In the later forms, such as *H. basanus* of the Wealden, the teeth differ from those of the typical Liassic forms by the taller, compressed, and nearly smooth crowns, and Mr Woodward suggests that it may eventually be advisable to refer these types to a distinct genus. The orbital hooks found in the Oxford and Kimeridge clay indicate fishes of very large dimensions.



Fig. 868.—Part of the palate of *Asteracanthus ornatissimus*, from the Great Oolite of Caen. Reduced. (After Owen.)

The genus *Acrodus* is closely allied to the preceding; but the teeth (fig. 867) are non-cuspidate and more rounded. This genus is abundant in the Lias, where it is represented by the large *A. nobilis*, which is the type; but it also extends downwards to the Muschelkalk, and ranges upwards as high as the Chalk. The majority of the species are European, but the genus has also been recorded from the Cretaceous of North America, as well as from certain beds in that country which have been stated to be Miocene.

Asteracanthus (*Strophodus*) agrees with *Hybodus* in the persistent notochord and the presence of orbital spines, but differs in the characters of the fin-spines and teeth (figs. 868, 869). The principal teeth form irregular rhomboids, with slightly arched and flattened crowns, marked by a reticulate ornamentation—the symphysial teeth being large, few, and simple. The fin-spines are marked by stellate tubercles, which are sometimes fused, and have two posterior mesial series of denticles. The type species (fig. 868) is of great size, and occurs typically in the Great Oolite of the Continent and England, but ranges upwards to the Kimeridge Clay, and thus presents a remarkable instance of persistence. This genus is also represented in the Purbeck. Other extinct genera are *Palæospinax*, from the Lias, and *Synechodus* from the English Chalk, both of which have teeth closely resembling those of *Hybodus;* but the fin-spines, at least in the former, were smooth, like those of *Cestracion.* The Cretaceous genus is the more specialised, and approximates in cranial structure to *Notidanus*, the palatopterygoid articulating directly with the cranium. Finally, the existing genus *Cestracion* (in which may be included forms described under the names of *Gyropleurodus* and *Drepanophorus*) occurs in Europe from the Kimeridgian of Bavaria to the London Clay, and is now represented by four species in the Australian and Japanese seas. This is a specialised genus differing from *Asteracanthus* by the absence of orbital spines, the numerous and small symphysial teeth (fig. 864), the smooth fin-spines, and the full calcification of the vertebral column.

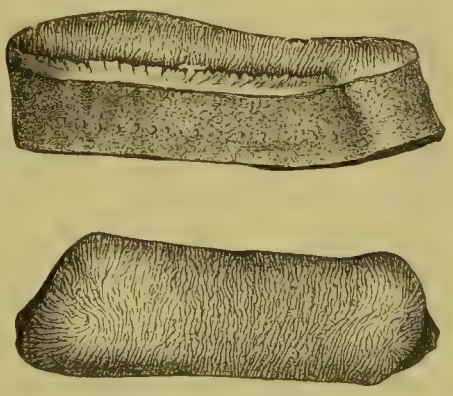


Fig. 869.—Lateral and oral surfaces of a tooth of *Asteracanthus ornatissimus*, from the Corallian of the Continent. (After Zittel.)

Family Scylliidæ.—This is a family of small extent, and most of the members of which are of relatively small dimensions. The dorsal fins have no spines, and the first is placed above or behind the pelvic fin; while the teeth are small and cuspidate, generally several series being simultaneously in use. The living forms are commonly known as Dog-fishes. *Palæoscyllium*, of the Lower Kimeridgian of Bavaria, seems to be allied to the existing *Ginglymostoma* and *Scyllium*. *Scylliodus*, of the English Chalk, is an imperfectly known form with teeth like *Scyllium*, but with vertebræ approximating to *Lamna*. *Scyllium* itself is represented in the Cretaceous of

the Lebanon and in the Continental Miocene; while allied extinct genera are *Pristiurus*, from the Lower Kimeridgian of Bavaria, and *Mesitia*, from the Lebanon beds. Finally, the existing *Chiloscyllium* occurs in the Miocene of Würtemberg; while *Ginglymostoma*, of which some of the existing species attain a length of 12 feet, is represented in the Eocene of Alabama.

Family Lamnidæ.—This family comprises the largest of the Sharks, and is characterised by having the first dorsal fin placed above the interval between the pectoral and pelvic fins, and without a spine. The teeth are acuminate, and when fully adult are solid throughout. The earliest form which has been referred to this family is *Carcharopsis*, known by detached teeth from the Carboniferous of Europe and North America. The type genus *Lamna*, in which *Otodus* may be included, comprises the existing Porbeagles, and has large lanceolate teeth (fig. 870) with basal cusps, but without marginal serrations. Teeth agreeing with those of existing forms in their general contour are found in Europe from the Lower Miocene (fig. 870) upwards, the so-called *L. acuminata*, from the Chalk, belonging, however, to the next genus. In another group of this genus, formerly known as *Otodus*, the teeth (fig. 871) are distinguished by the great compression of the crown, the large basal cusps, and the shortness of the root. Teeth of this type occur in Europe from the Gault to the London Clay, and are also represented in the Upper Cretaceous of Southern India and New Zealand. The nearly allied but extinct genus *Oxyrhina* is characterised by the still greater compression of



Fig. 870.—Tooth of *Lamna cuspidata*, from the Lower Miocene (Oligocene) of Germany. (After Zittel.)



Fig. 871.—Tooth of *Lamna appendiculata*, from the English Chalk.



Fig. 872.—Tooth of *Oxyrhina plicatilis*, from the Hungarian Miocene.

the crowns of the teeth (fig. 872), which are generally devoid of basal cusps. It has been recorded from the Jurassic, and occurs abundantly in the Chalk of Europe, India, and New Zealand, and is also represented in the European Miocene. Teeth from the Upper Cretaceous of Europe and India, differing from those of *Lamna* by the nearly circular section of their crowns, have been referred to the existing genus *Odontaspis;* but Mr S. Woodward considers that they belong to a genus from the Cretaceous of the Lebanon, originally described under the preoccupied name of *Rhinognathus*, but now known as *Scapanorhynchus*. *Odontaspis* itself occurs in the Eocene. Teeth of a long and slender type, from the Upper Jurassic and Lower Cretaceous, have been described under

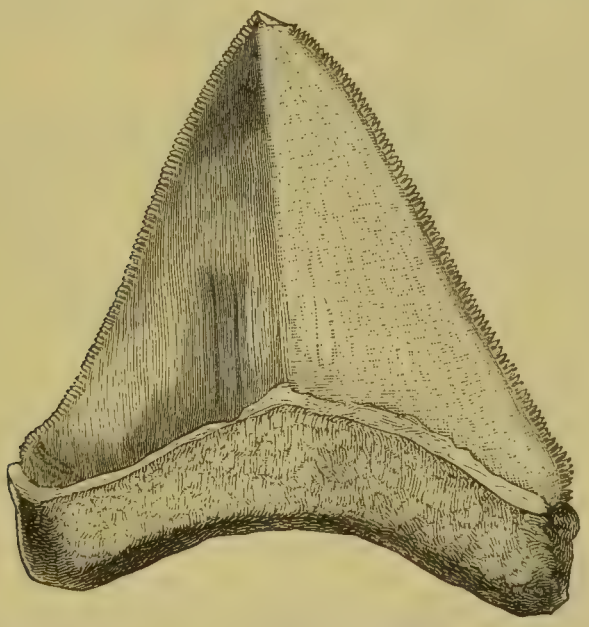


Fig. 873.—Tooth of *Carcharodon megalodon*, from the Miocene of Malta. (After Zittel.)

the name of *Sphenodus*, now changed to *Orthacodus*. Other teeth, from the Continental Miocene, have been referred to the existing genus *Alopecias* or "Threshers." With *Carcharodon* we come to Sharks of enormous size, characterised by their large, flat, and regularly triangular teeth (fig. 873), in which the edges are serrated, and there are no basal cusps. The one existing species attains a length of 40 feet, and has teeth measuring a little over 2 inches along the margins, with a basal width of 1.8 inches. It occurs fossil in the Pliocene of Europe. In the Red Crag, and also at the bottom of the Pacific, teeth are, however, found in which the corresponding dimensions are 5 and 4 inches, and thus indicate enormous indi-

viduals. Smaller teeth (fig. 873) also occur commonly in the Miocene of Malta, the Tertiary of New Zealand, and still smaller forms (fig. 874) in the Lower Miocene and Eocene of the Continent; and the genus is also represented in the Pliocene of Burma. Its earliest representative is, however, *C. longidens*, from beds which appear to be of the age of the Maastricht or topmost Cretaceous. Small compressed and triangular teeth, usually with serrated edges, from the Chalk of Europe and India, to which the name *Corax* has been applied, probably indicate Sharks allied to *Carcharodon*, although in external contour they approximate to the teeth of the next family: they have, however, solid crowns. The genus *Cetorhinus* (*Selache*), now represented by the huge Basking Shark, dates from the Pliocene.



Fig. 874.—Tooth of *Carcharodon productus*, from the Lower Miocene of the Continent. Reduced.

Family Carchariidæ.—The last family we have to mention is distinguished from the preceding by the presence of a nictating membrane to the eye, and also by the hollow crowns of the teeth. It is unknown before the Upper Cretaceous, and is dominant at the present day. The teeth have triangular and compressed crowns, usually with more or less distinctly serrated edges. The genus *Hemipristis*, of the Upper Chalk and Lower Tertiary, is characterised by its tall lanceolate teeth, the crowns of which have both edges coarsely serrated, except at their summits. The existing genus *Galeocerdo* is first recorded from the topmost Cretaceous of Holland, and occurs throughout the European and American Tertiaries from the Eocene upwards; the existing forms being known as "Topes." *Carcharias*, including the well-known Blue Shark, has small and generally triangular teeth, those of the upper being very different from those of the lower jaw. It may be divided into several groups from the structure of the teeth, which in some forms have smooth edges. It first occurs in the London Clay, and is thence found throughout the European Tertiary series; it has also been recorded from the Egyptian Eocene, and is found in the fresh-water Pliocene Siwaliks of north-western India. The strange Hammer-headed Shark, the only representative of the genus *Sphyrna* (*Zygæna*), has teeth so closely resembling those of *Carcharias* that it is almost impossible to distinguish detached specimens. It appears, however, that there is sufficient evidence to prove the existence of a species of the former genus in the Miocene of Europe and of the United States.

Ichthyodorulites.—In conclusion, a brief notice may be given of a few of the numerous genera founded upon the so-called "ichthyodorulites" or spines, of which the serial position cannot at

present be determined, and several of which are probably referable to the Chimeroidei. The earliest of these is *Onchus* (fig. 875, A), from the Silurian bone-bed of Ludlow, to which genus may also belong the dermal denticules (*ibid.*, B) described under the name of



Fig. 875.—Spine (A) of *Onchus tenuistriatus*, and (B) Dermal plates of *Thelodus*; from the Silurian of Ludlow.

Thelodus. In the Devonian of North America, and also in the Upper Silurian or Devonian of Bohemia, large spines have been described under the name of *Machæracanthus* (fig. 876), which probably belonged to the dorsal fins. *Gyracanthus* is based on

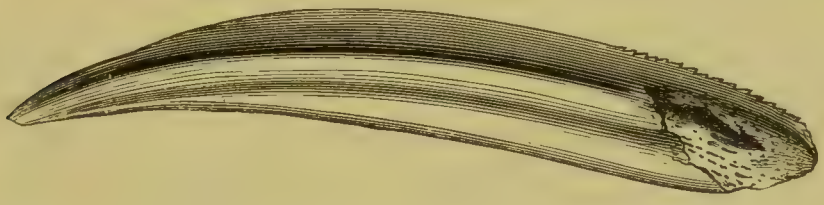


Fig. 876.—Fin-spine of *Machæracanthus major*; from the Devonian of North America. One-half natural size. (After Newberry.)

unsymmetrical spines (fig. 852, 2), which, it has been suggested, may belong to the pectoral fins. Other Carboniferous specimens have been named *Lophacanthus* and *Oracanthus* (England), *Euacanthus* (Russia), *Xystracanthus* (North America and India), and *Thaumatacanthus* (India). The spines described as *Oracanthus* are now known to belong to the head of a Selachian, and not, as at first supposed, to the tail of a Placodermic Ganoid. It will be unnecessary to mention a number of other types from various deposits; but we must not conclude without referring to the remarkable specimens (fig. 877) from the Carboniferous of North America and Australia, to which the name *Edestus* has been given. These have a highly curved axis, bearing compressed lancet-like teeth, with serrated edges



Fig. 877.—Part of (? caudal) spine of *Edestus vorax*; from the Carboniferous of North America. One-half natural size. (After Newberry.)

either on the convex or on both borders. It is suggested that they may have been carried on prominences in the caudal region. And after describing the best preserved remains of this genus, Dr Newberry concludes as follows: "Hence, until further light shall be thrown upon the interesting question of the homologies and functions of [the remains of] *Edestus*, we may regard them as the post-dorsal spines of large cartilaginous fishes, of which the other parts are yet unknown, and may suppose that they were used for attack and defence, like the spines of *Trygon* or *Acanthurus*."

Spines of similar type from the Carboniferous of Russia, originally described as *Edestus protopirata*, have been subsequently made the type of the genus *Protopirata*, although it is doubtful whether this term, having been first made a specific one, is admissible as a general one.

CHAPTER XLVIII.

CLASS PISCES—continued.

Orders Chimeroidei and Dipnoi.

Order III. Chimeroidei.—The Chimæroids are marine fishes, regarded by some writers as a suborder of Elasmobranchei; but although they resemble Sharks in external contour, in the presence of "claspers" on the pelvic fins of the male, and in the structure of the egg-capsules, yet they present such important differences as to indicate the propriety of referring them to a distinct order. The skeleton is entirely cartilaginous, and the vertebral column only imperfectly segmented; the notochord being surrounded by a series of cartilaginous rings, which may be partly calcified. The skin of the typical forms is usually quite naked in the adult, but in the young there is a row of small dermal ossifications on the back. The skull is movably articulated to the vertebral column, and has the hyomandibular fused with the palatopterygoid bar, and the latter firmly united to the cranium, with which the mandible consequently articulates without the intervention of a separate suspensorium—this arrangement being termed *autostylic*. The gill-clefts are four in number, and protected by a fold of skin containing a cartilaginous gill-cover; their communication with the exterior being effected by a single aperture. The mouth is always terminal; and in the recent forms each jaw carries one pair of molariform teeth, respectively attached to the palatopterygoid and Meckel's cartilage (mandible), with the addition of a smaller anterior pair of vomerine cutting-teeth in the upper jaw—all these teeth persisting throughout life. The fins are similar in structure and position to those of the Sharks; the first dorsal always carrying a strong spine, which articulates with the neural spines of the vertebræ, and is thus susceptible of motion. In the absence of a swim-bladder the Chimeroids, again, agree with the Elasmobranchs. There is a lateral line strengthened by cartilaginous rings. From the absence of any membrane bones, the

massive teeth, which are strictly comparable to those of the Dipnoi, constitute the whole of the solid part of the jaws.

This order may be regarded as in some respects connecting the Elasmobranchs with the Dipnoi—the autostylic cranium and the dentition being essentially Dipnoid. Chimæroids have existed from the Lias upwards, and not improbably date from the Devonian; while, as is usually the case, some of the extinct genera show much more generalised affinities than their existing representatives.

Family Squaloraiidæ.—The extinct genus *Squaloraia* was long regarded as an Elasmobranch of somewhat uncertain affinities; but according to the observations of Dr Traquair, it should find a place in the present order. In this genus, which is confined to the Lias, there is an elongated body; while the skull is produced into a long flat rostrum, and carries a basal pair of teeth separated at the symphysis, in advance of which are two small vomerine teeth of the normal Chimæroid type. Further, the skull of the male has a prehensile spine on the upper part of the snout, resembling in structure that found in *Ischyodus*. The "lateral line" agrees with that of other Chimæroids in being open, and protected by cartilaginous rings; while the skin appears to have been entirely naked. The vertebræ are of the Tectospondylic type of those of the Rays. The skull has been described as hyostylic, but Dr Traquair considers that this is due to crushing, and that it is really of the autostylic structure.

Family Chimæridæ.—Nearly all the remaining forms, from the Lias upwards, may apparently be included in this family, which is now represented by *Chimæra* and *Callorhynchus*. The teeth are of enormous size, those of opposite sides meeting in a median symphysis; and each tooth has one or more triturating ridges, or prominences, differing in appearance from the rest of the tooth, which may be conveniently termed *tritors*. The type genus *Chimæra* has the teeth adapted for cutting; those of the mandible being thin and plate-like, with one large median tritor, and two tritors near the anterior extremity, and an outer series in the form of dots; while the palatal tooth varies considerably in shape. This genus is represented at the present day by three species, and has also been recorded from the Pliocene of Italy and the Miocene of Bavaria. In *Elasmodectes* (*Elasmognathus*) of the English Chalk, the mandibular teeth are likewise of a cutting type, but without the median tritor. The extinct *Ischyodus*, which in England ranges from the Upper Jurassic to the Chalk, but has also been recorded from the Eocene of North America and the Cretaceous of New Zealand, appears to connect *Chimæra* with the next genus; the teeth being more adapted for crushing. The mandibular teeth are, indeed, more massive, and generally have two well-marked tritors externally to the large

median one; while there is a spine on the rostrum. *Edaphodon*, which ranges from the Lower Greensand to the Middle Eocene of Bracklesham, like the last genus, attains gigantic dimensions, but has its teeth adapted entirely for crushing. The mandibular tooth (fig. 878) is very massive, and has its symphysial surface (which in the preceding genera is narrow and grooved) very wide and quite flat, while there are two outer and one median tritors, as well as a terminal tritor which is not shown in the figure. Each palatal tooth is furnished with three tritors. Teeth of this genus are common in several Cretaceous and Tertiary deposits. *Elasmodus*, which is found in the Lower and Middle Eocene of England, appears to be

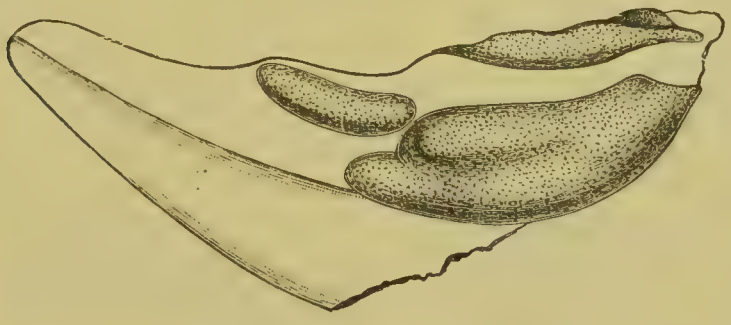


Fig. 878.—Inner surface of the right mandibular tooth of *Edaphodon gigas;* from the English Chalk. Reduced. (After Egerton.)

allied to the preceding genus; while in the existing *Callorhynchus* we apparently have the most specialised representative of the group with crushing teeth. The latter genus is represented by an existing species in the Southern seas, and by a fossil one from the Lower Cretaceous of New Zealand. The mandibular tooth is massive, with a narrow symphysis, and only a single tritor, representing the large median one of *Edaphodon.* Other European forms are *Ganodus*, from the Lower Jurassic of Stonesfield, in which the tritors of the mandibular tooth are confluent; and *Myriacanthus* (*Prognathodus* or *Metopacanthus*), of the Lower Lias of Dorsetshire, which is known both by the spines and the teeth. Its premaxillary teeth are chisel-like in shape. *Leptacanthus* of the Lias, and *Dipristis* of the Middle Miocene, are imperfectly known forms probably referable to this family. In North America the names *Eumylodus*, *Leptomylus*, *Byactinus*, *Diphrissa*, *Isotænia*, and *Sphageopœa* have been applied to Cretaceous forms, while a Miocene type has been called *Mylognathus;* but there is considerable doubt whether all these forms are really distinct from European genera.

As genera of which the family position is uncertain may be mentioned *Chimæropsis* from the Lower Kimeridgian of Bavaria, which differs from existing forms by its shagreen skin, and apparently also

by the presence of a remarkable spine-like tooth placed in front of the normal tooth of the mandible. The fin-spines of this genus approximate to those of the Elasmobranchian genus *Asteracanthus*. *Rhynchodes* from the Devonian of Ohio, and *Ptyctodus* from that of both Russia and Illinois, are genera founded upon teeth which their describers refer to this order. Some of the genera founded upon the evidence of detached fin-spines, a few of which are noticed in the preceding chapter, should perhaps also find a place among the Chimæroids.

Finally, the genus *Cœlorhynchus* may be mentioned in this connection. It was founded upon spines originally regarded as the rostra of Sword-fishes, but which are evidently of dermal origin, and are considered by Mr S. Woodward as being probably fin-spines of Chimæroids. These spines occur in the Chalk of England and Maastricht, in the Lower Eocene of England, Egypt, and India, and also in the Middle Eocene of Bracklesham in Sussex.

Order IV. Dipnoi.—The Dipnoi, which Dr Günther regards as a subdivision of the Ganoidei, are typically freshwater fishes, usually presenting the following characters: The body is covered with imbricating cycloidal scales, while the vertebral column is cartilaginous, and there are both anterior and posterior nostrils placed more or less within the mouth (fig. 881). The primitive cartilaginous cranium persists more or less completely, and, like that of the Chimæroids, is autostylic; cranial membrane bones are, however, always developed to a certain extent, and there are also splenial and articular bones in the mandible, while the cranium is immovably connected with the vertebral column. The palatopterygoid bar persists as the functional upper jaw, and, as in the living Chimæroids, carries a single pair of molariform teeth, while a corresponding pair of teeth are placed on the splenial and articular bones of the mandible. There is also a smaller pair of vomerine teeth; in advance of which there may be other minute teeth. The paired fins have a long, cartilaginous, jointed, median axis (fig. 845), and the tail may be either diphycercal or heterocercal. There are no functional branchiostegal rays; and the five or six cartilaginous branchial arches are more or less rudimentary, and their single aperture is closed by a gill-cover. The teeth agree with those of the Chimæroids in having no successors; but, from the presence of membrane bones, do not constitute the whole of the jaw.

In the structure of their skull the Dipnoi show affinities to Chimæroids, Ganoids, Teleosteans, and Amphibians; the autostylic feature connecting them with the former, and the double nares with the latter, in which the skull is also autostylic. The lungs are formed by the connection of the swim-bladder with the gullet by means of a duct, and these fishes can thus either breathe by means

of their gills in water, or by their lungs on land. In the existing African *Protopterus* there are external branchial tufts, like those of the young of the Amphibia. The structure of the pelvic girdle and limbs has been already noticed in the introductory chapter on the class; but it may be observed that although the skeleton is essentially cartilaginous, yet imperfect ossifications may occur in the neural spines of the vertebræ, as well as in the ribs and fin-rays. The scales may be either ganoid or cycloid.

That this order is essentially an old one, may be inferred not only from the widely scattered distribution of the three existing genera, and their paucity in species, and sometimes in individuals; but also from the generalised structure of its members, and the occurrence of one of the existing genera in the Trias of Europe, and the reputed Permian of North America.

Family Lepidosirenidæ.—This family is only known by two existing genera, and is characterised by the persistent chondrocranium, carrying a few large membrane bones, by the cycloid scales,



Fig. 879.—*Lepidosiren paradoxa*, from South America. Reduced.
p, Pectoral; *v*, Pelvic fin.

the absence of jugular plates, the continuous vertical fin, and the narrow central axis of the paired fins, which are reduced to filaments. The two genera are *Lepidosiren* (fig. 879) of the Amazons, in which the paired fins are not fringed; and *Protopterus* of the rivers of tropical Africa, where those fins are furnished with fringes. There

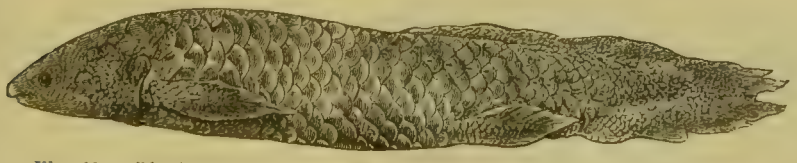


Fig. 880.—The Barramunda (*Ceratodus Forsteri*), from Queensland. Reduced.

are two small conical vomerine teeth, and larger cuspidate teeth on the palate, while the body is eel-like.

Family Ceratodontidæ.—The genus *Ceratodus* (fig. 880) has been generally placed in the same family as the preceding forms, with which it agrees in the continuous vertical fin, the cycloid scales, the absence of jugular plates, and the few cranial bones. In many

respects, and more especially as regards the dentition, *Ceratodus*, as pointed out by Dr Fritsch, is, however, much more nearly allied to the under-mentioned family *Dipteridæ*, and it seems advisable to regard it as representing, at least provisionally, the type of a distinct family.

Ceratodus is one of the very few instances where a genus, founded upon the evidence of fossil specimens, has subsequently been discovered in a living condition. Fossil teeth of this genus were long known, but it was not until the year 1870 that the existence of a living representative was brought to the notice of science. The body of the Barramundas, as these fishes are termed, is laterally compressed, with one continuous vertical fin; while the paired fins are paddle-shaped, with a broad fringe. The vomerine teeth (fig. 881, x) are shaped like the incisors of many mammals, while those on the palate (*ibid.*, xx) and mandible have an inner smooth convex border, and externally bear a number of strongly-marked ridges or horns. In the existing species the teeth of opposite sides are separated by a distinct interval (fig. 881), but in some fossil forms they were in contact. Again, in the living species, the palatal teeth bear six distinct horns, while the backward production of the inner margin forms an incomplete seventh horn (fig. 881); but in the mandibular teeth there are not more than the typical six horns. In fossil forms, according to Professor Miall, the mandibular teeth are slightly smaller and narrower than the palatal ones, and have not more than four horns; while the palatal teeth have either five horns, or four and a rudiment of a fifth (fig. 882); this simpler structure of the teeth in the earlier forms being analogous to that which we have already mentioned as obtaining in the Selachian *Notidanus*. Some of the fossil teeth indicate individuals of two or three times the size of the Barramunda, of which the largest specimens attain a length of nearly six feet. The position of these upper teeth on the palatopterygoid bar is well shown in fig. 881, which also ex-

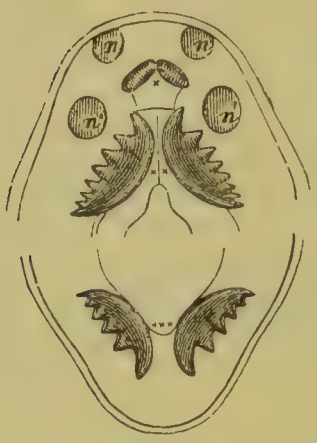


Fig. 881.—Mouth of *Ceratodus Forsteri*. Reduced. x, Vomerine; xx, Palatal; xxx, Mandibular teeth; *n*, anterior; *n'*, Posterior nares.

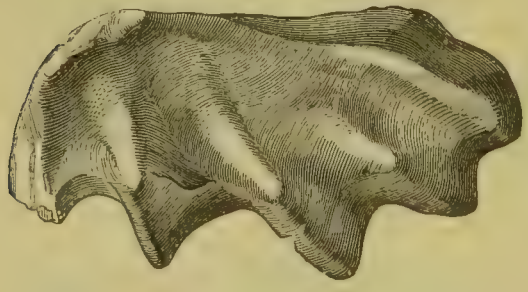


Fig. 882.—The right palatal tooth of *Ceratodus Hislopianus*, from the Lower Gondwanas of Maleri, India. The left side is the anterior border.

hibits the large parasphenoid, and the anterior and posterior nares. In regard to its distribution in past times, we meet with remains of this genus in the Jurassic of Colorado and Montana in the United States, and also in the Lower Jurassic of Stonesfield near Oxford; it is, moreover, abundant in the Upper (Keuper) and Middle (Muschelkalk) Trias of Europe, and has been recorded from the Lower division (Bunter) of that formation; it also occurs in Illinois in beds, which are thought to be probably Triassic; while in India teeth are very common in the Maleri group of the Gondwana system of the Central Provinces, which is not improbably also of Triassic age. Further, Professor Cope has recorded the genus from strata in North America identified by him with the Permian; but the species from the European Permian originally referred to this genus belongs to *Ctenodus*.

Family Phaneropleuridæ.—In this family, which has been placed by some in the Crossopterygian Ganoids, we still have the



Fig. 883.—*Phaneropleuron Andersoni*; from the Devonian of Scotland, one-half natural size. A, Scale magnified.

continuous vertical fin, the diphycercal caudal fin, and the narrow axis of the paired fins characteristic of the preceding families; but the scales are said to have a ganoidal structure, jugular plates are present, and there is a series of minute teeth in the margins of the jaws. This family is typically represented by *Phaneropleuron* (fig. 883), of the Devonian and Carboniferous of Scotland and the Devonian of Canada, and the allied *Uronemus* of the Scottish Carboniferous. We may, however, here mention the genera *Megapleuron*[1] and *Conchopoma* from the Permian of the Continent, which should probably find a place in this or an allied family. The former genus has

[1] The rhomboidal scales which have been described as belonging to this genus are those of a Ganoid. The name should properly be *Megalopleurum*.

ossified ribs, large operculars, and Dipnoid teeth, but the form of the fins and tail is unknown; while the latter agrees with *Phaneropleuron* in the structure of the teeth and tail.

Family Dipteridæ.—This family is characterised by the great development of the cranial bones, the more or less ganoidal structure of the scales, the presence of jugular plates, the heterocercal tail, the two distinct dorsal fins, and the greater size and breadth of the scaled portion of the paired fins. Its range extends from the Devonian to the Permian, and it shows signs of connecting the preceding family with the Crossopterygian Ganoids. The teeth (fig. 885) are of the same general type as those of *Ceratodus*, but may carry a larger number of smaller ridges, which in some instances (fig. 885, 1, 2) are ornamented with a number of cusps or denticules. The typical genus *Dipterus* (fig. 884) comprises fishes of small or medium size, with circular scales, and both the dorsal fins placed in the hinder third of the body, the first being much smaller than the second. The pectoral fins are long and paddle-

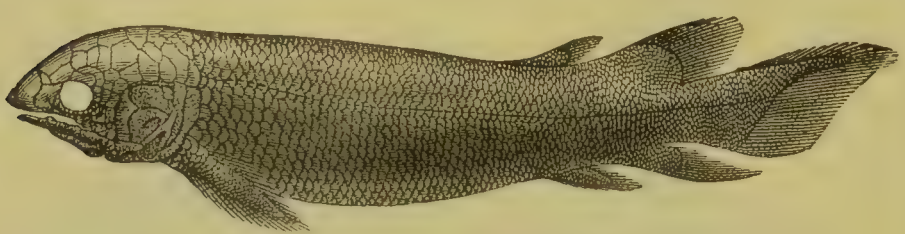


Fig. 884.—*Dipterus Valenciennesi*; from the Devonian of Russia, two-thirds natural size. (After Pander.)

shaped; while the pelvic pair, and the anal, are respectively placed beneath the first and second dorsals. The quadrate is ossified; and there are also ossifications in the fin-rays and ribs. The teeth (fig. 885, 1) carry numerous denticules on their ridges. This genus is characteristic of the Devonian (Old Red Sandstone) of Europe. *Ctenodus* attains considerably larger dimensions than the preceding genera; some of the species reaching a length of nearly five feet. The teeth are characterised by their ridges carrying many cusps; and the scales are large and thin, with a rhomboidal contour, and bearing traces of rows of denticules, with vascular grooves on the inner side. The skeleton closely resembles that of *Ceratodus*, but is more fully ossified; and both this feature and the more numerous cranial bones are regarded by Dr Fritsch as characters of greater specialisation. The teeth (fig. 885, 2, 3) are frequently simpler than those of *Dipterus*, and thus approximate to those of *Ceratodus*; while the form of the parasphenoid and palatopterygoid differs considerably from that in the former. This genus ranges in Europe from the Carboniferous to the Permian, being very abundant in the

former; and it is also recorded from strata in Illinois and Texas which are correlated with the European Permian.

As members of this order, but perhaps indicating one or more distinct familes, we may class the following genera: *Palædaphus*, from the Devonian of Europe and Ohio (the species from the latter area having been separated as *Heliodus*), is a moderately large form in which the mandibular teeth (fig. 885, 4) are very broad, and carry

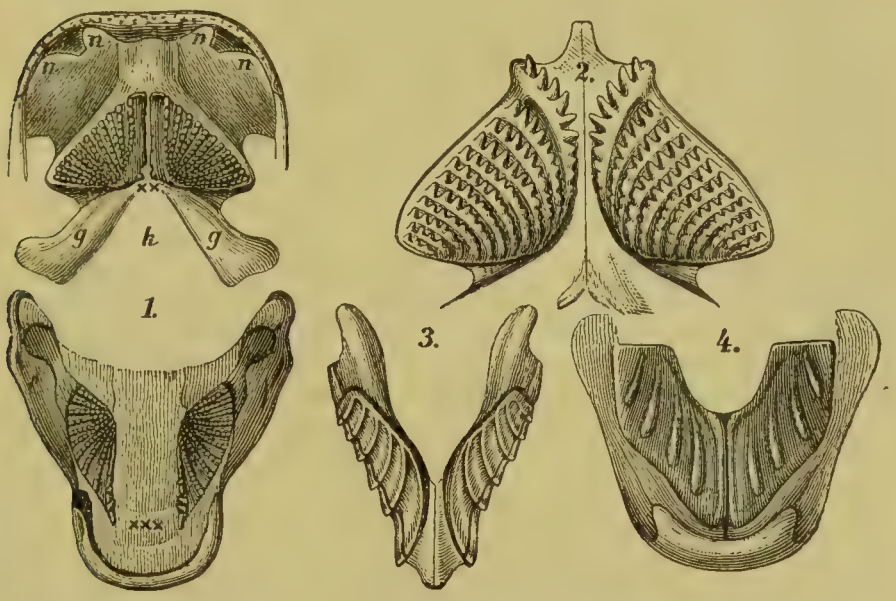


Fig. 885.—1, Upper and lower jaws of *Dipterus Valenciennesi;* from the Devonian. xx, Palatal; xxx, Mandibular teeth; *n*, *n*, Narial processes; *g*, Palatopterygoid. 2, Palate of *Ctenodus tuberculatus;* Carboniferous. 3, Mandible of *Ctenodus imbricatus;* Carboniferous. 4, Mandible of *Palædaphus insignis;* Devonian. All reduced.

only four low ridges. *Holodus*, from the Devonian of Russia, is a smaller form very imperfectly known, but apparently allied to the preceding; while *Conchodus* is known by teeth from the same deposits in both Scotland and Russia. *Ganorhynchus*, of which the horizon is unknown, may also be provisionally placed here. From North America we have *Ptyonodus* and *Gnathorhiza* from the Permian, and *Mylostoma* from the Devonian, of which the full affinities require further elucidation.

CHAPTER XLIX.

CLASS PISCES—continued.

Order Ganoidei.

Order V. Ganoidei.—The Ganoids form an order exceedingly difficult of definition, owing to their close connection on the one hand with the Dipnoi and (through the Acanthodea) the Elasmobranchei, and on the other with the Teleostei, and it is not improbable that it may be eventually necessary to divide them into at least two orders. As mentioned above, some writers group them in a subclass with the Teleostei under the name of Teleotomi. The body may be either naked or covered with shagreen skin, or with large detached bony scales, or completely covered either with true ganoid scales, or with cycloidal scales of a ganoid structure. The vertebral column, again, may be either cartilaginous or fully ossified; and its termination in the tail may be either diphycercal or heterocercal. Paired and median fins are generally present, and the pelvic pair (with perhaps one exception) is abdominal in position. The skull may either be covered merely by cranial membrane bones, or may be completely ossified. It is hyostylic—*i.e.*, there is a hyomandibular suspensorium—and the palatopterygoid is distinct from the cranium; and, as a general rule, even in the cartilaginous forms maxillæ and dentary bones, which carry the teeth, are developed on the palatopterygoid and Meckel's cartilage respectively. The gills are usually free, and their single aperture is covered by an operculum; while branchiostegal rays are very generally present. In most cases a secondary pectoral girdle of dermal bones (clavicular, supraclavicular, &c.) is developed externally to the cartilaginous scapulo-coracoidal girdle, which alone exists in the preceding orders. Finally, there is a swim-bladder, with a duct into the pharynx; while there are some other characters of the soft parts into the consideration of which it will not be necessary to enter in this work.

Some very curious features occur in the ossification of the ver-

tebral column of certain members of this order which call for passing notice. Thus in *Eurycormus* the ossifications in the dorsal region consist of an upper and a lower hollow, wedge-shaped, semi-cylinder, with their pointed extremities interlocking, and the former bearing the neural arches and the latter the ribs; while in the tail we have two centra to each neural arch. From this it would appear that the pieces bearing the ribs in the dorsal region, and the caudal centra which have no arches, correspond to the intercentra of the Amphibia, which are noticed below. The teeth of Ganoids vary greatly in structure, and may be either conical and borne on the margins of the jaws, when they are continuously replaced, or flattened disks attached to the vomer, which have no successors. The borders of the fins are frequently furnished with the modified scales known as fulcra.

Considerable diversity of view has prevailed as to the classification of Ganoids; but the system of Dr Traquair, who has paid especial attention to the structure of the order, is adopted in this work.

As regards their distribution in time, Ganoids first appear in the Silurian nearly at the same time as the Elasmobranchs; and from the Devonian to the close of the Mesozoic they form a very large proportion of the Fish-life of those periods. Their wane, however, appears to have set in during the Upper Cretaceous, when the Teleostei began to be numerically strong; and from that date there has been a rapid decrease to the present day, when we find only one of the suborders (Amioidea) represented by several genera; while of the other three surviving suborders one is represented by two genera, and each of the other two by a single genus—these four genera each having a solitary species.

A. Proganoid Series.—The first three suborders may be conveniently grouped in a single series, and are mainly characterised by their exceedingly low development, their affinities being still doubtful. Professor Cope is indeed disposed to regard one of these suborders (Placodermata) as more nearly allied to the Tunicata than to other Vertebrata; but this view is scarcely likely to find acceptation with the majority of palæontologists.

Suborder 1. Cephalaspidea.—The members of this extraordinary group have the head and the anterior part of the body covered with a continuous shield, while the rest of the body is coated with small angular plates or scales. No traces of an inner skeleton, lower jaw, or teeth, have yet been discovered; but at least in the second family there was a strong pectoral fin at the hinder extremity of the dorsal shield. The latter has been recently shown to be furnished with a system of sensory canals. This group is confined to the Silurian and Devonian; and it is suggested by Professor Huxley that it may be allied to the Acipenseroidea.

Family Pteraspididæ.—The entire body in this family is unknown; but the dorsal shield (figs. 886, 887) is usually composed of several pieces united together, and has its borders thickened and



Fig. 886.—Imperfect dorsal shield of *Cyathaspis Banksi*; from the Silurian of Ludlow. (After Murchison.)



Fig. 887.—Dorsal shield of *Pteraspis rostrata*; from the Lower Devonian of Hereford. Reduced. (After Lankester.)

bent, and in structure approaches the scales of Teleostean Fishes. It has a median posterior spine, and sometimes small lateral cornua. There is also a small shield on the ventral aspect of the fish, which, like the dorsal one, is marked by fine striations. In the type genus *Pteraspis*, the dorsal shield (fig. 887) is shaped like an arrow-head, and composed of seven pieces; while in *Cyathaspis* (fig. 886) it is oval, composed of only four elements, and has the posterior spine very short. *Scaphaspis* has been founded on

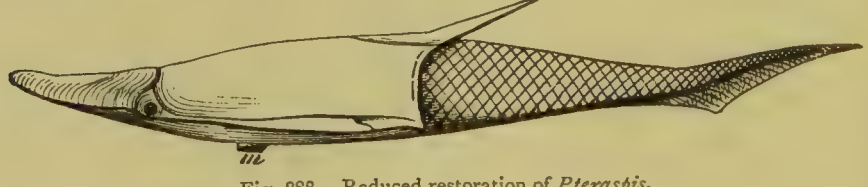


Fig. 888.—Reduced restoration of *Pteraspis*.

remains belonging to these two genera, which are found in both the Silurian and Devonian; the simple shields described under this name having apparently been placed ventrally beneath the more complex ones, on the evidence of which the other genera were

founded. *Holaspis*, from the Lower Devonian of North Wales, is distinguished by the dorsal shield, consisting of only a single element. Figure 888 is an attempt to restore the form of the type genus.

Family Cephalaspididæ.—The Cephalaspids are regarded by some writers as belonging to the *Pteraspididæ*, while by Professor Zittel they are placed in a distinct suborder. The dorsal cephalic shield (fig. 889) consists of one or two pieces, and usually has more or less developed lateral cornua, with a regularly curved and flat lower border—the eyes being situated near the middle; in structure it resembles true bone. The body is covered with bony plates, and the caudal fin is heterocercal. The typical genus *Cephalaspis* (figs.

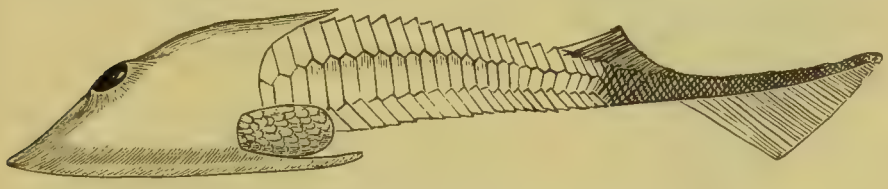


Fig. 889.—Left lateral view of *Cephalaspis Lyelli*; from the Devonian of Scotland. About one-third natural size. (After Lankester.)

889, 890) has the cephalic shield single, and may be divided into the *Eucephalaspidine* and *Hemicephalaspidine* groups, according to the degree of development of the cornua. It occurs in the Silurian and the Devonian of Britain, and has also been obtained

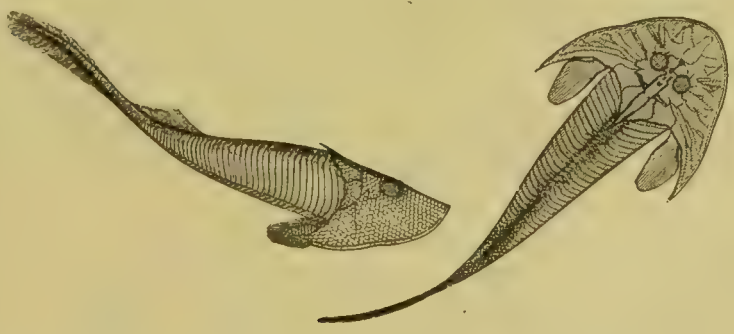


Fig. 890.—Smaller views of *Cephalaspis Lyelli*. (After Page.)

from the Silurian of Bohemia and the Devonian of Canada. *Xenaspis*, from the same English formations, is distinguished by the presence of one or more quadrangular dorsal plates behind the head; while *Auchenaspis*, of the European Silurian, has the cephalic shield transversely divided. *Didymaspis*, from the same formation, agrees with the latter in its double cephalic shield, which is, how-

ever, unprovided with cornua; while other genera are *Thyestes* and *Trematapis*, from the Silurian of Russia.

Suborder 2. Placodermata.—This suborder is mainly characteristic of the Devonian, although represented also in the Silurian, and lingering on till the Permian. It is characterised by the cartilaginous vertebral column, and the enclosure of the head and the anterior part of the body in bony plates, which are covered with a radiate or granular sculpture; the tail being either naked or clothed with scales. There is a distinct mandible; teeth are frequently present; and there may be a jointed pectoral fin enclosed in a bony covering like that of the body, but pelvic fins are invariably absent.

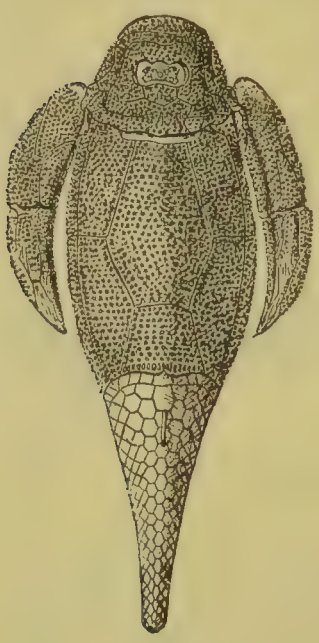


Fig. 891.—Reduced restoration of the dorsal aspect of *Asterolepis ornata*; from the Devonian of Russia. The tail is restored from *Pterichthys*. (After Pander.)

Family Asterolepididæ. — In the typical family the head (figs. 891, 892) is rounded anteriorly, and covered with a number of small thin plates; while the body is sub-quadrangular and invested with larger plates, some of which are median and others paired; and the tail may either be covered with much smaller scales or naked. There is a well-developed pectoral limb, which articulates with the anterior ventro-lateral plate; although it was long thought to articulate in some forms to a separate thoracic plate. The type genus *Asterolepis*, which occurs both in Russia and Scotland, is characterised, according to Dr Traquair, by the anterior median dorsal plate overlapping both the anterior and the posterior dorso-laterals, and by the somewhat depressed body. In *Pterichthys* (figs. 892, 893), on the other hand, the median dorsal plate, while overlapping the anterior dorso-laterals, is itself overlapped by the posterior dorso-laterals, and the body is much more elevated. This genus has been recorded from Scotland and the Eifel, and probably also occurs in Russia. Detached pectoral fins of these genera have been described under several names, and were at one time regarded as ichthyodorulites.

The genus *Bothriolepis*, from the Devonian of Europe and Canada, is distinguished by the different contour of the cephalic plates, and of the grooves of the lateral line system by which they are marked, as well as by the shorter limbs. No traces of the scaly tail have been observed in any of the known specimens, although

Dr Traquair considers that this appendage was probably present. Some of the species attained very large dimensions.

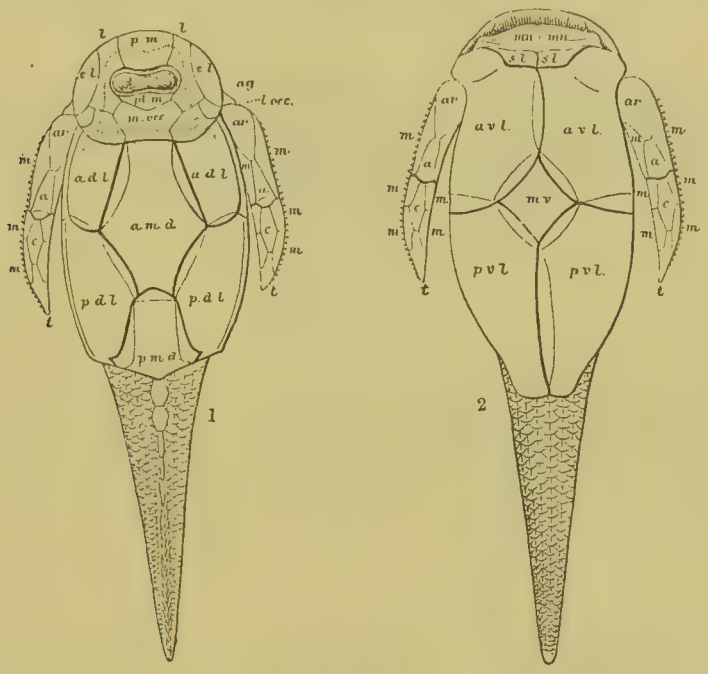


Fig. 892.—Reduced restoration of the dorsal (1) and ventral (2) aspects of *Pterichthys cornutus*, with the sculpture omitted; from the Devonian of Scotland. The thin black lines indicate the concealed edges of the overlapped plates, and the double dotted lines the grooves of the lateral line system. *m.occ*, Median occipital plate; *l.occ*, Lateral do.; *ag*, Angular plate; *pt.m*, Post-median do.; *p.m*, Premedian do.; *l*, Lateral do.; *e.l*, Extra-lateral do.; *mn*, Mental do.; *s.l*, Semilunar do.; *a.m.d*, Anterior median dorsal do.; *p.m.d*, Posterior do. do.; *a.d.l*, Anterior dorso-lateral do.; *p.d.l*, Posterior do. do.; *a.v.l*, Anterior ventro-lateral do.; *p.v.l*, Posterior do. do.; *m.v*, Median ventral do.; *ar*, Articular plate of limb; *a*, Anconcal of do.; *c*, Central of do.; *m*, Marginal of do. (After Traquair.)

Microbrachius, of the Scottish Devonian, is an allied form distinguished by the smaller size of the pectoral limb; in this form also

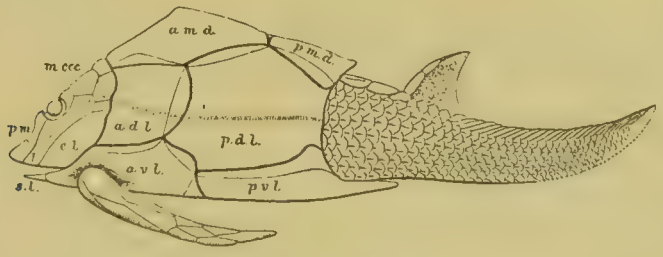


Fig. 893.—Reduced left lateral aspect of *Pterichthys cornutus*; from the Devonian of Scotland. Letters as in the preceding figure. (After Traquair.)

no caudal scales have been observed. The length of the head and carapace in the one known species is one and a quarter inches.

Family Coccosteidæ.—The genus *Coccosteus* differs so markedly from the members of the preceding family that Dr Traquair has suggested that it should form the type of a distinct suborder. The head has distinct bones and plates differing markedly in their arrangement from those of the preceding family, but their structure has only recently been rightly explained (fig. 894). In the restoration given by Agassiz (fig. 895), although the arrangement of the posterior plates is fairly correct, yet anteriorly the grooves of the lateral line were mistaken for sutures; while the ethmoidal bones at the muzzle and the orbital notches are omitted. An approximation to a correct restoration of the lateral aspect is shown in fig. 896, but the mouth is made too long. The carapace, or body-shield, consists of a long shield-shaped middle dorsal plate, flanked by lateral plates, and completed by a median ventral plate. The posterior half of the body is totally unprotected, but interspinous bones in the vertebral column support an anal and a

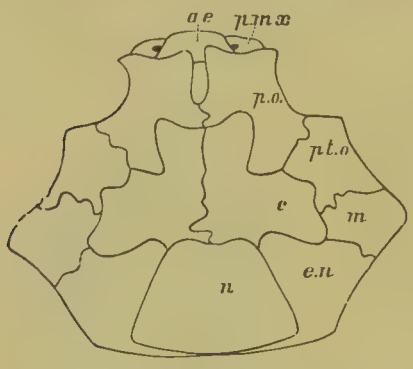


Fig. 894.—Dorsal aspect of the cranium of *Coccosteus decipiens;* from the Devonian of Scotland. *ae*, Ethmoidal, with nares of either side; *p.m.x*, Premaxilla; *p.o*, Preorbital, external to which is the orbit; *pt.o*, Postorbital; *c*, Central, *m*, Marginal, *n*, Middle occipital; *e.n*, Lateral do. (After Traquair.)

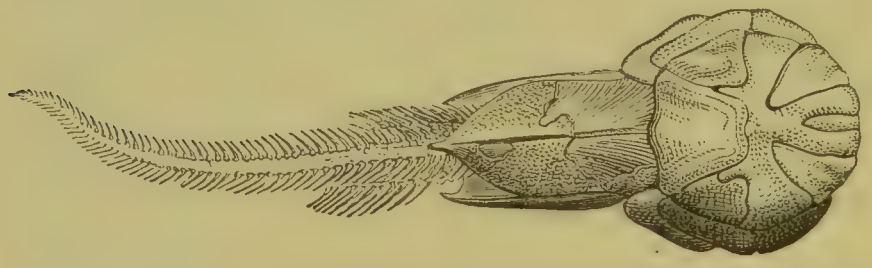


Fig. 895.—Dorsal view of *Coccosteus decipiens*, as restored by Agassiz. In the anterior part of the head the ethmoids and orbits have been omitted, and the black lines mostly indicate the grooves of the lateral line system, and not sutures. The shield-shaped plate immediately behind the skull is the middle dorsal, in advance of which is the middle occipital of the skull.

dorsal fin. There appears to have been no pectoral fin, although certain forms which have been generically or subgenerically separated as *Brachydirus* have been represented with such an appendage. Both this and the next genus are characteristic of the Devonian, *Coccosteus* being common to Europe and Canada. The allied *Homosteus* includes gigantic forms from Scotland and the Eifel, readily distinguished by the form of the cranial and body plates. Thus the middle occipital plate is longer and narrower, and the middle dorsal wider than long, and not pointed behind. Professor Huxley

compares the armour of the Coccosteans to that of the Siluroid Teleosteans; while Newberry and Pander compare the ventral armour with the plastron of the Chelonia and Labyrinthodontia, with

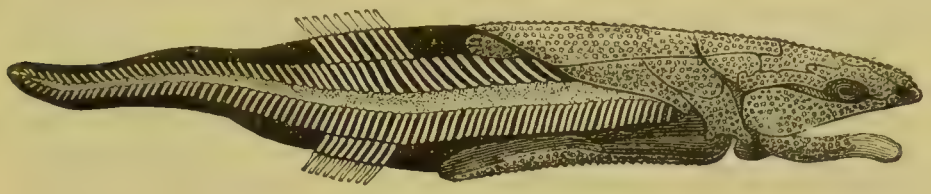


Fig. 896.—Approximate restoration of the right lateral aspect of *Coccosteus decipiens*. Here the ethmoids and orbits are introduced, but the skull and mouth are made too long.

which, however, they also compare the true pectoral girdle of the Sauropterygia. The nature of the dentition is unknown.

Family Dinichthyidæ.—The genus *Dinichthys*, from the Devonian (Huronian) of North America, may probably be regarded as forming the type of a family allied to the preceding. In this genus, of which the type species has an estimated length of from 15 to 18 feet, the dentition (fig. 897) is remarkably like that of the Dipnoid



Fig. 897.—Diagrammatic anterior aspect of the jaws of *Dinichthys Hertzeri*; from the Devonian of North America. One-twelfth natural size. (After Newberry.)

genus *Protopterus*, from which Dr Traquair concludes that there was probably a close connection between the present group and the Dipnoi. Other gigantic forms more and less closely allied to the type genus are *Titanichthys*, *Liognathus*, and *Diplognathus*, from the Devonian of Ohio; while *Typodus*, from the same formation in the Eifel, may perhaps belong to this family.

As Placodermata, of which the serial position is uncertain, may be mentioned *Menaspis*, from the Permian of Germany; *Acanthaspis*, *Acantholepis*, and *Aspidichthys*, from the Devonian of Ohio; *Pnigeacanthus* and *Lecracanthus*, from the Carboniferous of Iowa; *Stichacanthus* and *Phoderacanthus*, from the corresponding formation of Ireland and Belgium; and *Anomalichthys*, from the Devonian of Germany.

Suborder 3. Acanthodea.—The last group of the Proganoids is also Palæozoic, and ranges from the Devonian to the Permian, although it is not improbable that some of the genera, founded upon fin-spines, which are noticed under the Elasmobranchei, should be

placed in it. The Acanthodeans appear to be in some respects intermediate between the Ganoids and Elasmobranchs, and should perhaps constitute an order by themselves. They have the body, which is more or less elongated and compressed, covered with shagreen-like scales, and with the lateral line running between two rows of such scales. The tail is heterocercal; and the fins have strong spines, which, except in the pectorals, are merely inserted between the muscles. There is considerable doubt as to the presence of cranial bones or of a gill-cover; but there is a ring of bones round the orbit. The vertebral column is cartilaginous, and teeth are either wanting or are very minute and sharp.

In their cartilaginous skeleton, the not improbable absence of an operculum, the structure of the scales and position of the lateral line, as well as in the spines of the median fins, the Acanthodea approach the Elasmobranchei; but the articulation of the pectoral fin-spine to the pectoral girdle is a character of the Teleostean *Siluridæ*, while the orbital ring is a character of the higher Ganoids like the *Palæoniscidæ*.

Family Acanthodidæ.—All the genera may be provisionally



Fig. 898.—*Acanthodes;* from the Permian of Europe. (After Kner and Roemer.)

included in a single family, of which the type genus *Acanthodes* (fig. 898), as now restricted, ranges from the Carboniferous to the Permian of Britain and the Continent. The head is very short and blunt, and there is but a single dorsal fin placed immediately above the anal, while it is thought that teeth were absent. *Mesacanthus*, of the Scottish Devonian, includes small fishes distinguished from the last genus by the presence of an intermediate pair of small spines between the pectoral and pelvic fins; it is represented in the Devonian of Canada. Closely allied is *Acanthodopsis*, from the Carboniferous of Northumberland, in which there were numerous minute teeth; while *Chiracanthus* (fig. 899, 1), of the Scottish Devonian, is distinguished by the dorsal fin being placed in advance of the anal. In *Diplacanthus* (fig. 900) there are two dorsal fins, of which the second is placed above the anal; each pectoral fin has two spines; while there are minute spines between the pectoral

and pelvic fins, and the jaws are furnished with small conical teeth. This genus is represented by several species in the Devonian of Scotland, and not improbably also occurs in that of Canada. *Rhadinacanthus*, from the Scottish Carboniferous,

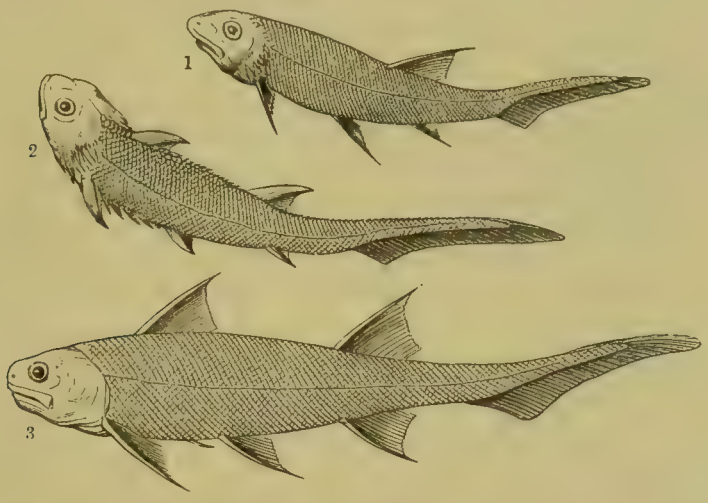


Fig. 899.—1, *Chiracanthus Murchisoni*; 2, *Climatius scutiger*; 3, *Ischnacanthus gracilis*; from the Devonian of Scotland. Reduced.

has two in place of four pectoral spines; while in *Ischnacanthus* (fig. 899, 3), of the same deposits, the small intermediate spines are wanting, although they are introduced in the figure. Allied to the last are *Euthacanthus* and *Parexus*, from the Scottish Devonian, the former having the second dorsal in advance of the anal

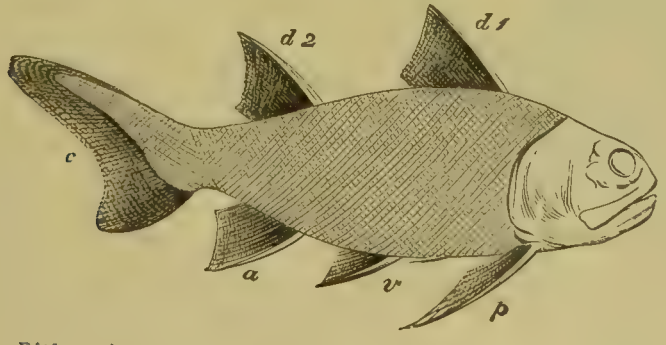


Fig. 900.—*Diplacanthus striatus*; from the Devonian of Scotland. *p*, Pectoral; *v*, Pelvic; *a*, Anal; *c*, Caudal; d^1, d^2, First and second dorsal fins. Reduced.

fin. Finally, the genus *Climatius* (fig. 899, 2) includes three small fishes from the last-named formation characterised by the short fin-spines and the presence of a series of accessory spines between the pectoral and pelvic fins. There are two dorsal fins, of which the

second is behind the anal, the figure being incorrect in the latter respect. Fin-spines from the Devonian of Canada, described as *Ctenacanthus* and *Homacanthus*, are referred by Mr Woodward to *Climatius*.

Incertæ Sedis.—Here may be noticed the family *Tarrasiidæ*, proposed by Dr Traquair for the imperfectly known genus *Tarrasius*, from the Scottish Carboniferous, which is regarded as indicating an aberrant type.

B. Euganoid Series.—The remaining members of the order include its typical representatives, and may be collectively known as the Euganoid series or the Ganoidei Veri.

Suborder 4. Crossopterygea.—In this group the pectoral, and sometimes the pelvic, fins consist of a central lobe surrounded by a fringe; there is an infraclavicular in the pectoral girdle; the rays of the dorsal and anal fins are often more numerous than the supporting interspinous bones; the preopercular extends forwards on the cheek; branchiostegal rays are replaced by jugular plates; the development of the vertebral column varies; the tail may be either diphy- or heterocercal, and the scales cycloidal or rhomboidal. This suborder is the most primitive of the true Ganoids, among which it holds a position somewhat analogous to that occupied by the Ichthyotomi in the Elasmobranchei.

Family Holoptychiidæ.—In the type family the pectoral fins are acutely, and the pelvic subacutely, lobate; the skeleton of the former, according to Dr Traquair, being a biserial archipterygium like that of *Ceratodus*. The teeth are of the so-called *dendrodont* type, the dentine of the base being infolded in an extremely complex manner, with cross-branchings which form an intricate network within the crown. The scales are cycloidal, thick, and sculptured; and there are two dorsal fins, and a heterocercal tail in which the inferior rays are much longer than the superior. Before noticing the typical forms we may briefly mention the genus *Onychodus*, from the Devonian of North America and Europe, which Dr Newberry considers may be allied to this family. The scales (fig. 901) have distinct ridges, and the mandible has a presymphysial production furnished with teeth arranged somewhat like an old-fashioned cavalry spur. The type genus *Holoptychius* (fig. 902) comprises fishes, which are often of large size, from the Devonian of Europe and North America. The two dorsal fins are placed in the hinder part of the body directly over the pelvic and anal. We may probably place here the imperfectly known



Fig. 901.—Scale of *Onychodus sigmoides*; from the Devonian of North America. (After Newberry.)

Platygnathus, from the Devonian of Scotland and Russia; *Isodus*, of the Irish Carboniferous; and *Peplorhina*, from the Trias of Illinois. In *Glyptolepis* (fig. 903), from the European and Canadian Devonian, we have a well-known form in which the dorsal fins are placed more anteriorly than in *Holoptychius*, while the anal is situated below the first dorsal, and the pelvic are consequently much

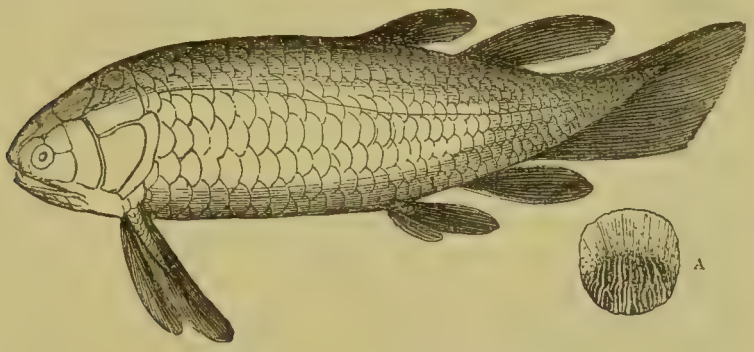


Fig. 902.—*Holoptychius nobilissimus*; from the Devonian of Scotland. A, A scale less reduced. The dorsal and anal fins should be more pointed.

more approximated to the pectoral fins. *Phyllolepis*, founded on very thick scales, which are sometimes smooth, from the Devonian and Carboniferous of Scotland, should probably be included in this family, in which Dr Traquair also places the imperfectly known genus *Dendrodus*, of the Devonian of Russia and Scotland. The jaws of the latter carry a small row of marginal teeth of conical form; while in the mandible there is a second row of much larger fang-like teeth, each of which has a distinct socket. These teeth

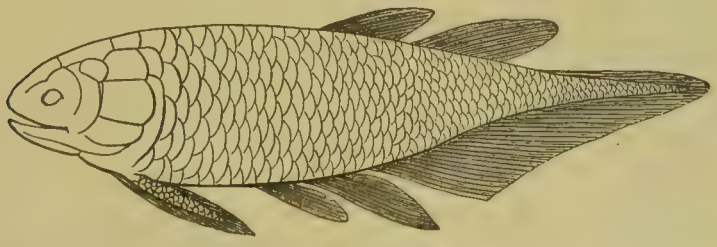


Fig. 903.—Restoration of *Glyptolepis*; from the Devonian of Scotland. Reduced. (After Huxley.)

are somewhat compressed, with trenchant fore-and-aft edges, and have the internal structure already noticed. *Colonodus*, of the British Carboniferous, and *Sigmodus*, of the Upper Palæozoic of northern India, should perhaps find a place in this family.

Family Rhizodontidæ.—In the Rhizodonts the pectoral fins are subacutely or obtusely lobate, the pelvic pair being usually non-

lobate; while their internal skeleton forms a shortened uniserial archipterygium. The teeth are labyrinthodont in structure, lacking the complex internal network found in the preceding family. The scales are cycloidal and sculptured; the median fins are numerically the same as in *Holoptychius;* but the tail approximates to the truly diphycercal type. The lower jaw has an inner series of tusk-like teeth (fig. 905). As an imperfectly known form we may first mention *Cricodus* (*Polyplocodus*) from the European Devonian. In the well-known *Tristichopterus*, of the Scottish Devonian, the body is much elongated, the tail distinctly heterocercal, the posterior fins are placed near the tail, the opercular bones are unusually large, and the scales thin and striated. An apparently allied form is *Eusthenopteron* of the Devonian of Canada, in which the vertebral centra appear to have been unossified, while there are slight differences in the interspinous bones, tail, and teeth. According to the views of Dr Traquair, *Gyroptychius* (fig. 904), from the Devonian of Scotland, is allied to *Tristichopterus*, having scales of the same general type (although some of these were formerly thought to be rhomboidal), but a more rhomboidal tail, and the exposed portion of the scales relatively larger. From the Carboniferous of both Europe and North America we have the type genus *Rhizodus* (*Megalichthys* in part), of which the typical species attained a very large size. The larger teeth (fig. 905), on the evidence of which the genus was originally founded, have the upper half of the crown smooth, while the lower half is longitudinally fluted. The teeth of large individuals (which may attain a length of nine feet) are nearly two inches in height. In *Rhizodopsis*, of the same deposits, the cranial bones form a well-developed shield on the superior surface resembling that of the *Osteolepididæ*, although the mandible agrees in general structure with that of *Rhizodus*, and consists of articular, angular, and dentary elements; the latter having a series of *infra-dentary* pieces on its inner side which carry the large tusk-like teeth. The inferior space between the mandibular rami is occupied by a series of jugular plates, of which there is a large median pair, together with a small unpaired anterior

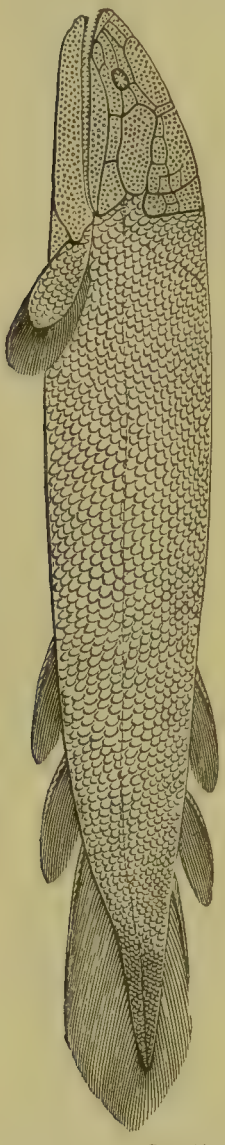


Fig. 904.—*Gyroptychius angustus*; from the Devonian of Scotland. Reduced. (After Pander.)

one, and a row of small lateral ones on either side. In the cranium the most striking feature is the anterior position of the orbit, which has three large suborbital bones behind it. Other more imperfectly

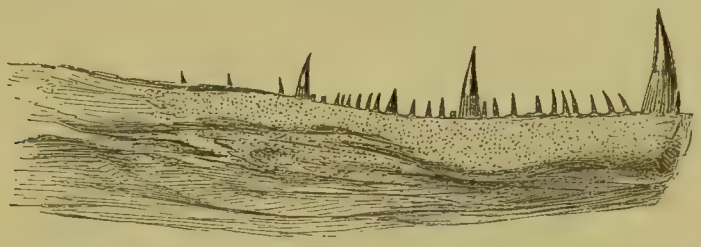


Fig. 905.—A mandibular ramus of *Rhizodus Heberti*; from the Carboniferous of Scotland. Reduced.

known genera of this family from the European Carboniferous are *Dendroptychius*, *Strepsodus*, *Rhomboptychius*, and *Archichthys*.

Family Osteolepididæ (Rhombodipteridæ).—In this family the fins have the same general structure as in the preceding; but the scales are of the rhomboidal form typical of the order. There are a number of lateral jugular plates; the teeth are numerous and sharply-pointed; and the ossification of the vertebral column is

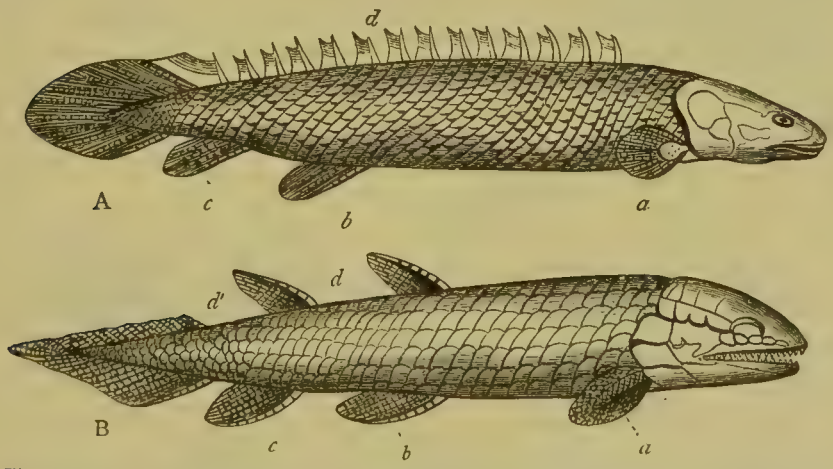


Fig. 906.—A, *Polypterus bichir*; from the Upper Nile. B, *Osteolepis macrolepidotus*; from the Devonian of Russia. (After Pander.) Both figures reduced. *a*, Pectoral; *b*, Pelvic; *c*, Anal; *d*, *d'*, Dorsal fins. In the lower figure the dorsal fins should be placed more in advance of the pelvic and anal.

imperfect. The family is divided into two subfamilies; the first, *Osteolepidinæ* (*Saurodipterini*) being characterised by the smooth scales, and presence of a median jugular plate. The type genus *Osteolepis* (fig. 906, B) has a long and slender body, with the two dorsals placed respectively in advance of the pelvic and anal fins. The type species is of considerable size. In the allied *Thursius*, of

which an immature individual is shown in fig. 907, the dorsals are placed immediately over the pelvic and anal fins. Both genera occur in the Devonian of Scotland and Russia. Closely allied is the genus *Diplopterus*, from the Scottish Carboniferous, in which the dorsal fins are also situated posteriorly, the first being directly over the pelvic. *Megalichthys*, from the same deposits, comprises two species of large size; and is characterised by the presence of large fulcra at the roots of the pectoral, pelvic, and anal fins; and also by the

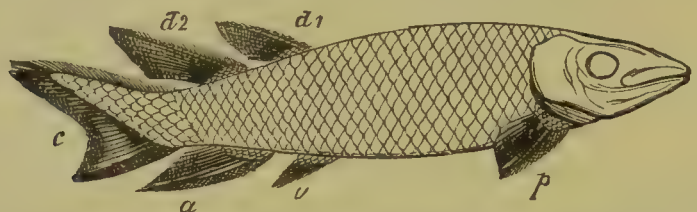


Fig. 907.—A young individual of *Thursius macrolepidotus;* from the Devonian of Scotland. Letters as in fig. 900. Reduced. (After Sedgwick and Murchison.)

small size of the anterior dorsal fin, which is placed above the pelvic fin. *Ectosteorhachis*, from the Permian of North America, is nearly related, and appears to be the last survivor of the family. The second subfamily, or *Glyptolæminæ*, is represented only by the genera *Glyptolæmus* (fig. 908) and *Glyptopomus*, of the Scottish Devonian; and differs from the last by the sculptured scales, and the absence of a middle jugular plate. The body is much elongated; there is a long interval between the pectoral and the posterior

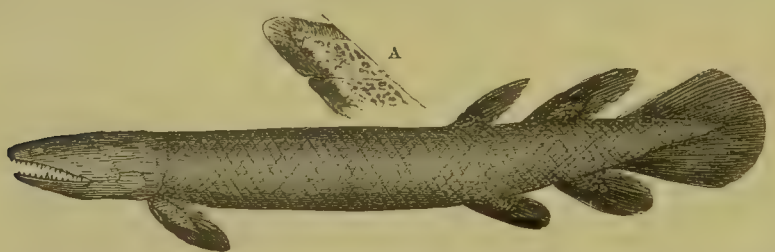


Fig. 908.—*Glyptolæmus Kinnairdi;* from the Devonian of Scotland. Reduced. A, Scales. (After Huxley.)

fins; and the tail is truly diphycercal; each genus is represented by a single species.

Family Cœlacanthidæ.—With this family we come upon a group of fishes not occurring in the older Palæozoic, but extending from the Carboniferous to the Upper Cretaceous, and thus affording a link between the preceding extinct and the following existing family. The vertebral column is unossified; there are two dorsal fins, each of which is supported by a single forked interspinous bone; the pectoral fins are obtusely lobate; the caudal fin is un-

usually large, and completely diphycercal; the swim-bladder is ossified, and the scales are cycloidal. The members of this family are further characterised by the full development of the cranial bones; and the arrangement of the ossifications in the orbit ap-

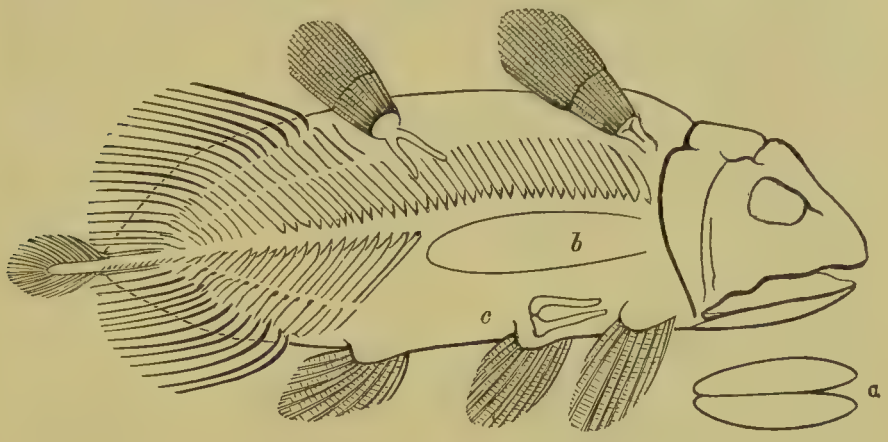


Fig. 909.—Skeleton of *Undina penicillata*; from the Kimeridgian of Bavaria, one-fourth natural size. *a*, Jugular plates; *b*, Swim-bladder; *c*, Pelvis.

proaches that found in the Labyrinthodontia. The type genus *Cœlacanthus* ranges from the Carboniferous of Europe and North America to the Upper Trias of the former area, and is well characterised by the great thickness of its scales.

More or less nearly allied are *Diplurus* from the Trias of New

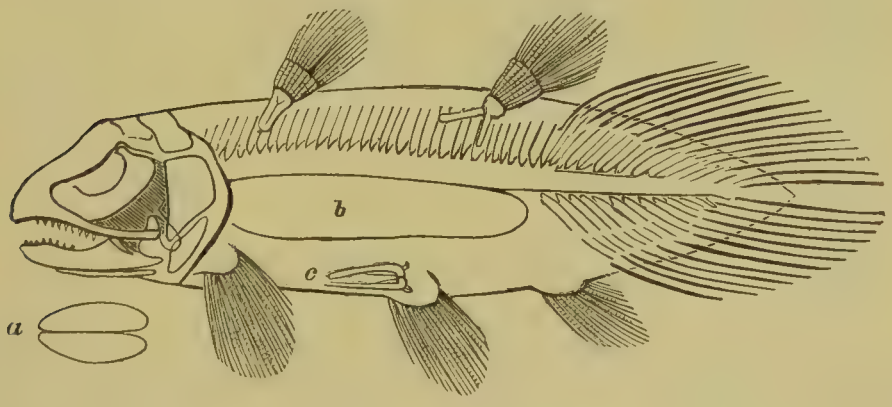


Fig. 910.—Skeleton of *Macropoma Mantelli*; from the Chalk of Sussex. Reduced. Letters as in fig. 909. (After Huxley.)

Jersey, *Graphiurus* from the Upper Trias of Carniola, and *Heptanema* ranging from the Middle Trias to the Upper Jurassic of the Continent. In *Undina* (fig. 909) the exposed parts of the scales are marked by ridges, rising in some parts into spines, and the

rays of the dorsal and caudal fins are divided and furnished with spines. In the English Liassic *Holophagus* the spines on the scales are more numerous, while in *Libys*, from the Kimeridgian of Bavaria, they are less numerous, the division of the fin-rays extends more deeply than in *Undina*, and the dorsal and caudal scales have a row of tubercles. *Coccoderma*, from the Kimeridgian of Europe, is allied to the last. Finally, *Macropoma* (fig. 910), from the Chalk, comprises several large species readily characterised by the notochord not extending to the extremity of the tail.

Family Polypteridæ.—The last family of the suborder is known only by the existing African genera *Polypterus* (fig. 906, A) and *Calamoichthys*, each of which is represented by a single species. The vertebral column is ossified; the dorsal fin broken up into a number of small finlets; the pectorals are obtusely lobate; the caudal fin is diphycercal, with a very short body-axis; and the scales are rhomboidal.

Suborder 5. Acipenseroidea.—According to the views of Dr Traquair, the Acipenseroids, represented typically by the Sturgeons and their allies, and forming the Chondrostei of many authors, are also taken to include the Heterocerci, as represented by the extinct *Palæoniscidæ*. The following are some of the leading features of the group as thus defined. The paired fins are non-lobate; the pectoral girdle, which in the typical forms retains its primitive endoskeletal cartilages, develops dermal bones, among which the infraclavicular (fig. 913) is characteristic; the dermal rays of the dorsal and anal fins are more numerous than their supporting cartilages, or interspinals, of the endoskeleton; while in the paired fins these dermal rays have to a great extent replaced the original cartilages. In the skull the cartilaginous cranium persists in the typical forms, but in all cases it is overlain by a series of dermal bones; the preopercular, when present, tends to extend on to the cheek; branchiostegal rays are generally present; but there are never large jugular plates. The notochord is persistent, but there are either cartilaginous or bony neural and hæmal arches; the tail is heterocercal, and the skin may be either naked, or dotted over with bony scutes, or covered with rhomboidal scales.

Mr Smith Woodward remarks that the typical forms of this suborder constitute a link connecting the cartilaginous Ganoids with these fishes in which the bones are fully developed, and that their paired fins are more specialised than the median ones, which have not yet attained a numerical equality between the fin-rays and their supporting interspinals.

Family Acipenseridæ.—The well-known Sturgeons (fig. 911), which form the typical family, are large fresh-water fishes, characterised by their elongated body, produced snout, toothless jaws of

the adult, the presence of five rows of scutes formed of true bone on the body, and the sculptured cranial bones. The representatives of the existing genera *Acipenser* (fig. 911) and *Scaphirhynchus* are found in many of the larger rivers of the Northern Hemisphere. Scutes referred to *Acipenser* occur in the London Clay, and in some higher Tertiary beds; while spines from the English Upper Eocene

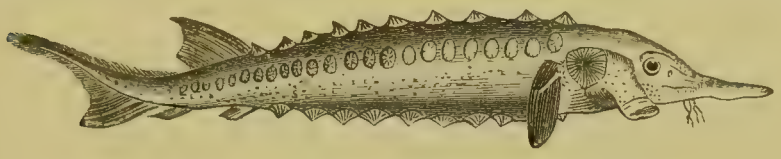


Fig. 911.—The Sturgeon (*Acipenser sturio*). Much reduced.

and the Pliocene of Montpellier probably also belong to the same genus. A single scute has also been described from the Miocene of Virginia under the same name.

Family Polyodontidæ.—In this family, now represented by *Polyodon* of the Mississippi and *Psephurus* of two rivers in China, the skin is typically nearly or quite naked, the mouth is of enormous width, and the jaws carry minute teeth. In a fossil state this family is represented by *Crossopholis*, from the Eocene of Wyoming, which displays many points of resemblance to *Polyodon*, but is remarkable for the possession of small pectinated scales, which are not confined to the upper lobe of the tail. The cranial bones are of the type of those of *Polyodon*, but the shorter rostrum indicates a resemblance to *Psephurus*. The scales are numerous, and are arranged in oblique rows, which are not quite in contact with one another. The retention of the scales in this genus indicates that we have to do with a much less specialised member of the family than the existing forms. The genus *Macropetalichthys*, from the Devonian of both North America and the Eifel, has frequently been referred to the *Polyodontidæ*, but without any sufficient evidence, and its serial position must for the present remain undetermined. The cranium (fig. 912) is short and broad, with the orbits completely surrounded by bone, and the middle line occupied anteriorly by a diamond-shaped ethmoidal shield, which articulates posteriorly with a process from the squared hinder shield.

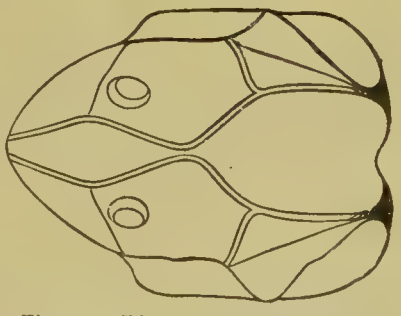


Fig. 912.—Diagram of the frontal aspect of the cranium of *Macropetalichthys Sullivani*; from the Devonian of North America. Much reduced. (After Newberry.)

As an Acipenseroid of uncertain position may also be mentioned the imperfectly known *Pholidurus*, of the English Chalk—the tail of which presents some resemblance to that of *Psephurus*. A huge fish from the English Upper Lias, named *Gyrosteus*, is evidently also an Acipenseroid agreeing with the type genus in the absence of teeth, but having a naked body. It differs also considerably from the type of the next family, and its position must remain uncertain.

Family Chondrosteidæ.—This family is formed for the reception of the one comparatively small fish constituting the genus *Chondrosteus* from the English Lower Lias. According to Dr Traquair, although there is no evidence of a long snout (fig. 913), this genus resembled *Polyodon* in the general form of the fins, and of the nearly naked body; but in other respects—such as the form of the cranial bones and the absence of teeth—approaches *Acipenser*. Certain features also appear to indicate distinct affinity with the

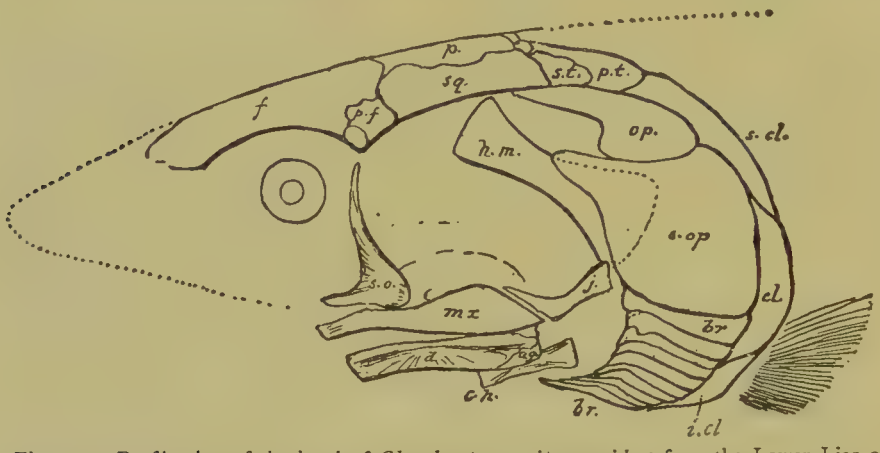


Fig. 913.—Profile view of the head of *Chondrosteus acipenseroides;* from the Lower Lias of Dorsetshire. Reduced. *f*, Frontal; *p.f*, Postfrontal; *p*, Parietal; *sq*, Squamosal; *s.t*, One of the supratemporals; *p.t*, Posttemporal; *s.cl*, Supraclavicular; *cl*, Clavicular; *i.cl*, Infraclavicular; *op*, Opercular; *s.op*, Subopercular; *br*, Branchiostegals; *c.h*, Ceratohyal; *ag*, Angular; *d*, Dentary; *mx*, Maxilla; *j*, Jugal; *h.m*, Hyomandibular; *s.o*, Suborbital. (After Traquair.)

Palæoniscidæ; and since the latter are evidently allied to the higher bony Ganoids, Mr Woodward suggests that they or allied forms may have given origin to two series, one of which culminated in the Teleosteans, while in the other "the only advance has been in the matter of size, and this accompanied by a certain amount of degeneration, culminating in Acipenseroids proper."

Family Palæoniscidæ.—This and the next family constitute the suborder Heterocerci of some writers. In the present family the body is fusiform, and covered with rhomboidal scales; the vertebral arches are ossified, but there are no bony ribs; the dorsal fin is single and short; all the fins have large fulcra at their bases; the

cranial bones are covered with ganoine, and mostly sculptured; the mouth is large; the first branchiostegal rays form jugular plates; there is a row of median V-shaped scales on the superior surface of the extremity of the body; and the teeth are small, conical, or cylin-

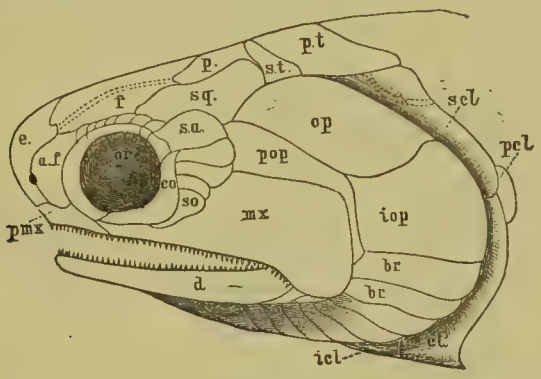


Fig. 914.—Left lateral view of the skull of *Palæoniscus macropomus*; from the Permian. *p*, Parietal; *f*, Frontal; *sq*, Squamosal; *s.t*, Supratemporal; *p.t*, Posttemporal; *e*, Ethmoid; *a.f*, Prefrontal; *pmx*, Premaxilla; *mx*, Maxilla; *co*, *sa*, *so*, Suborbitals; *d*, Dentary; *op*, Opercular; *p.op*, Preopercular; *iop*, Subopercular; *br*, Branchiostegals; *cl*, Clavicular; *scl*, Supraclavicular; *pcl*, Postclavicular; *icl*, Infraclavicular; *or*, Orbit. (After Traquair.)

drical, and rarely plicate at the base. The chief characters of the bones of the skull and of the secondary pectoral girdle are shown in fig. 914, in which it will be seen that the preopercular covers a portion of the face above the large and broad maxilla. Dr Traquair observes that if a Palæoniscid were stripped of its scales and furnished with a long snout, it would be so like *Polyodon* that there would be no doubt as to their near relationship; and he further remarks that the one row of V-shaped scales found on the dorsal side of the extremity of the body in *Polyodon* is identical with the row of scales occupying the same position in *Palæoniscus*. This leads to the conclusion that the existing Sturgeons are the survivors of a series of Ganoids, now totally lost, which formerly gave off the *Palæoniscidæ* and *Platysomidæ* as specialised branches.

This family embraces such a large number of genera, that space permits of but little more than their bare enumeration. In the Devonian *Chirolepis*, found both in Europe and Canada, the body is slender, and the fins are large, with the rays very finely divided; while *Rhabdolepis* (fig. 915) of the Rothliegendes (Lower Permian), while having fins of somewhat similar structure, is distinguished by the deeper and more spindle-shaped body. *Cosmoptychius*, of the Scotch Carboniferous, is allied to *Rhabdolepis*, but has the anal fin with a longer base. In the type genus *Palæoniscus* (figs. 914, 916) the body is much elongated, and the fins are very small and widely separated. It occurs in the Kupfer-Schiefer and Magnesian Lime-

stone (Middle Permian) of Germany and England; and one species has been said to occur in the English Trias. That species is, however, now referred to the *Dapediidæ;* but a true *Palæoniscus* is recorded from the Hawkesbury beds of New South Wales, which may be of Triassic age. The remaining better known genera are *Elonichthys*, from the Carboniferous of Europe and America; *Acro-*

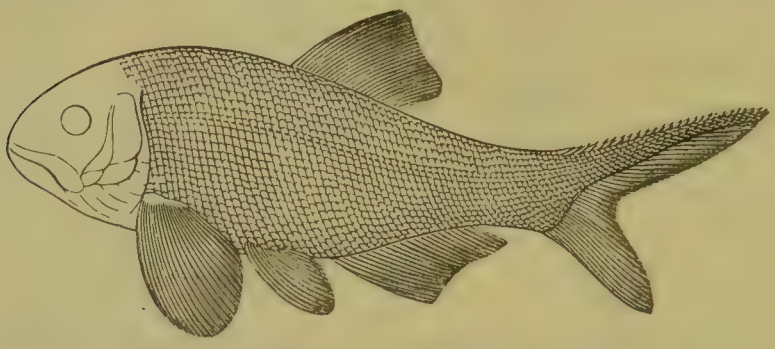


Fig. 915.—*Rhabdolepis macroptera;* from the Lower Permian of Saxony. Reduced. (After Agassiz.)

lepis, ranging from the Permian to the Carboniferous, and perhaps to the Devonian, of Europe; *Nematoptychius*, *Cycloptychius*, *Micronodus*, and *Gonatodus*, from the British Carboniferous; the gigantic *Amblypterus*, of the German Permian; *Rhadinichthys*, from the Carboniferous of both Europe and North America; *Eurylepis*, from the Carboniferous of Ohio; *Holurus*, *Canobius*, and *Phanerosteon*, of the Scottish Carboniferous; *Pygopterus*, of the German Permian; *Myriolepis*, from the Hawkesbury of New South Wales; *Urosthenes*, from the underlying Newcastle group of the latter country; *Gyro-*

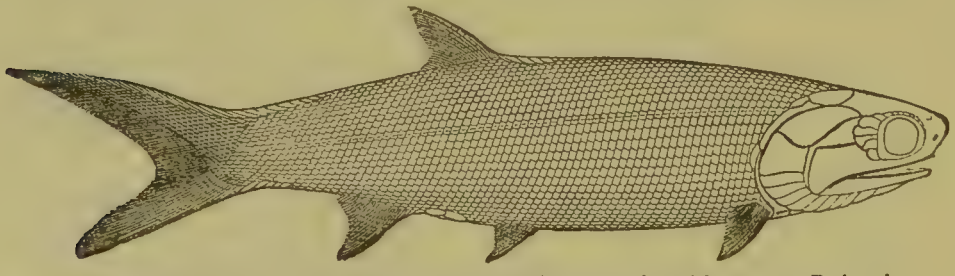


Fig. 916.—*Palæoniscus macropomus;* from the Middle Permian of Germany. Reduced. (After Traquair.)

lepis, from the Middle Trias of the Continent; and *Oxygnathus*, *Cosmolepis*, *Thrissolepis*, *Centrolepis*, and *Lissolepis*, from the English Lias. Here also may be mentioned the genera *Sphærolepis*, of the Permian of Bohemia, and *Coccolepis*, of the Kimeridgian of Bavaria, which, although having cycloidal imbricating scales, appear to be allied to the present family.

Family Platysomidæ.—The *Platysomidæ* agree with the preceding family in the characters of the vertebral column, fins, scales, and the main cranial structure, but differ by the body becoming deep and short, with an ovoid or rhomboidal contour, and also by minor modifications in the cranial structure. The teeth are small, and may be either sharp or obtuse. The chief difference in the structure of the skull consists in the deflection of its axis below that of the vertebral column, instead of being continuous; while the hyomandibular, instead of being very oblique, becomes nearly vertical, and the ethmoid is elongated. These changes cause the mouth to be separated widely from the orbit, the jaws to become "prognathous," and the gape of the mouth itself to be much reduced; they are readily apparent by contrasting the figure of *Palæoniscus* with that of *Chirodus*. Dr Traquair regards this family as a group of specialised forms descended from the *Palæoniscidæ;* their external resemblance to the *Dapediidæ* being probably due merely to adaptation to similar conditions of life, and not indicating a real affinity. In *Eurynotus* (fig. 917) the contour of the body is not so greatly

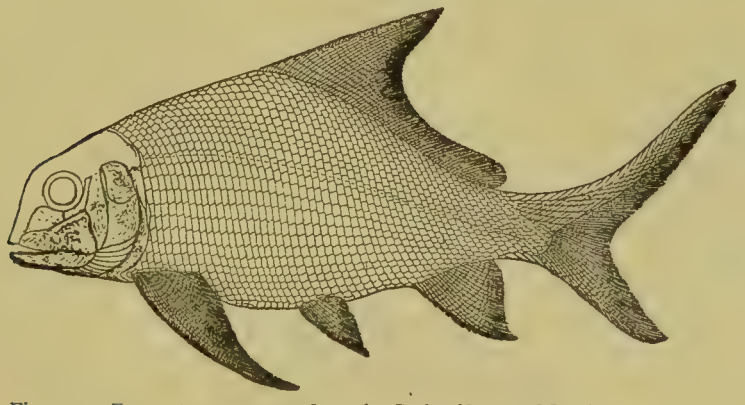


Fig. 917.—*Eurynotus crenatus;* from the Carboniferous of Scotland. Reduced. (After Traquair.)

removed from the Palæoniscid type; the pectoral fin is large, the dorsal also large, and beginning above the pelvic, while the base of the anal is short. This genus occurs in the Carboniferous of Scotland and Belgium. In *Benedenius*, of the Belgian Carboniferous, the body becomes more oval, and the dorsal fin is placed more posteriorly. More or less nearly allied to this group are *Mesolepis*, of the British Carboniferous; *Eurysomus*, of the Middle Permian of England and Belgium; and *Wardichthys*, of the Scottish Carboniferous. In *Chirodus* (fig. 918), of the British Carboniferous, the body is rhomboidal; the dorsal and anal fins have a long base, short rays, and an anterior spine; while the pelvic fin is unknown, and the pectoral small. Closely allied, again, is *Chirodopsis*, from

the same horizon. The last and type genus *Platysomus* (figs. 919 and 920) is represented by a large number of species, ranging from the Carboniferous of England and North America to the Middle

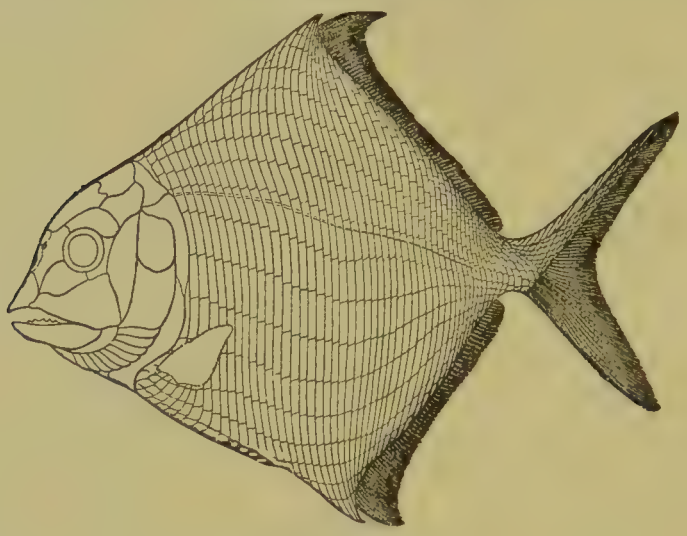


Fig. 918.—*Chirodus granulosus;* from the Carboniferous of Scotland. Reduced. (After Traquair.)

Permian of England and the Continent. The contour of the body is less rhomboidal than in *Chirodus;* the dorsal and anal fins have no anterior spines; the pelvic fin is very small, and but seldom preserved; while the pectoral is of medium size.

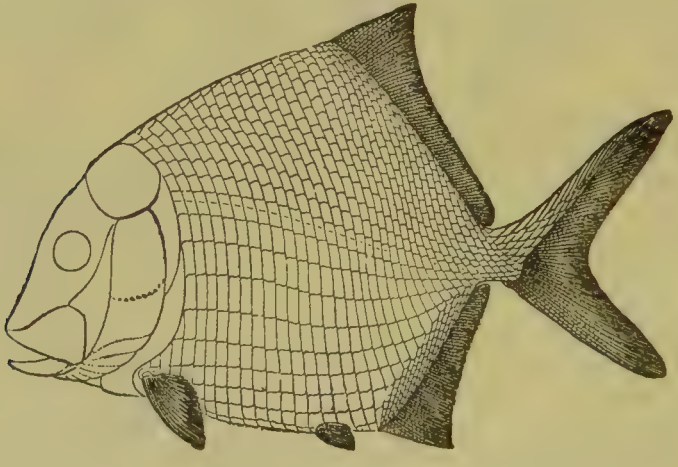


Fig. 919.—*Platysomus striatus;* from the Middle Permian of England. Reduced. (After Traquair.)

Suborder 6. Lepidosteoidea.—In the Lepidosteoids the paired fins are non-lobate; there is no infraclavicular bone; the rays of

the dorsal and anal fins correspond in number with their supporting interspinous bones; the opercular bones are like those of the Teleostei; there is frequently a median jugular plate on the first pair of branchiostegals; the development of the vertebral column varies; the tail is of the masked heterocercal type; and the scales are rhomboidal, or may be occasionally replaced by angular scutes. This

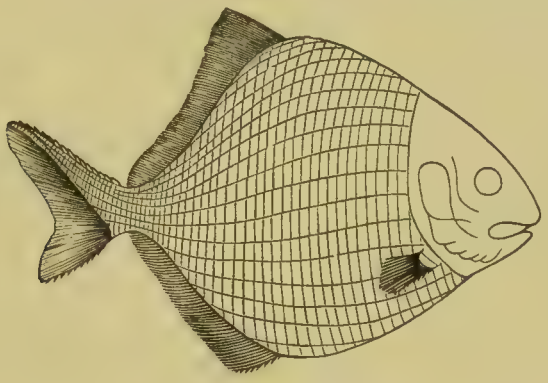


Fig. 920.—*Platysomus gibbosus*; from the Middle Permian of Germany. Reduced. The pelvic fin is not shown.

suborder is represented at the present day by the somewhat aberrant *Lepidosteidæ*, and also by a large number of Mesozoic forms ranging from the Trias upwards. As already mentioned, the external resemblance of the *Dapediidæ* and *Pycnodontidæ* to the *Platysomidæ* is not regarded by Dr Traquair as indicative of real affinity.

Family Dapediidæ.—In this family, which by some writers is subdivided and known as the *Sauridæ* and *Stylodontidæ*, the body is either fusiform or ovate; the opercular bones present certain

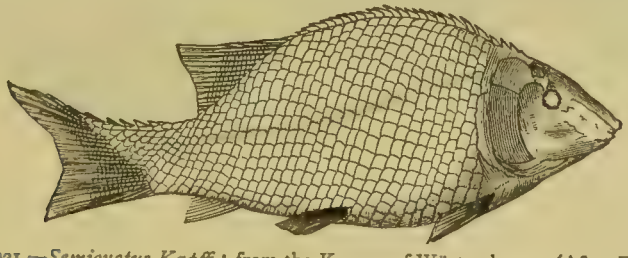


Fig 921.—*Semionotus Kapffi*; from the Keuper of Würtemberg. (After Fraas.)

characteristic features; the upper lobe of the body-axis of the tail, and usually the anterior borders of the other fins, have well-developed fulcra; the vomer and jaws carry several rows of small teeth, of which the outermost are curved and resemble claws (*griffelzahne*); and the ossification of the vertebral column is imperfect. Among the genera with fusiform bodies, one of the best known is *Semionotus*

(fig. 921), which is widely spread over Europe. According to Dr Deecke, this genus is represented in the Bunter and Muschelkalk; it is common in the Keuper, or Upper Trias, and thence ranges to the Kimeridgian, or Upper Jurassic. It has also been recorded from the Stormberg beds in the upper part of the Karoo system of South Africa; and it appears to be also represented in the Trias of North America, where it has received the name of *Ischypterus*. In these fishes the dorsal fin is small, the inequality of the scaled portion of the caudal strongly marked, and there is a row of large spine-like scales on the middle line of the back. Other more or less nearly allied forms, of which some were formerly included in *Palæoniscus*, are *Acentrophorus*, from the British Permian; *Catopterus*, from the North American Trias; and *Dictyopyge*, from the Trias of both England and North America, the type species of the latter having been originally named *Palæoniscus superstes*. In *Heterolepidotus*, typically from the Lower Lias of England, and *Heterostrophus*, from the Kimeridgian of Bavaria, we have genera in which the contour of the body is more like that of the type genus. *Heterolepidotus*, according to Dr Deecke, is also represented in the Muschelkalk, and survived to the Kimeridgian. The name *Allo-*

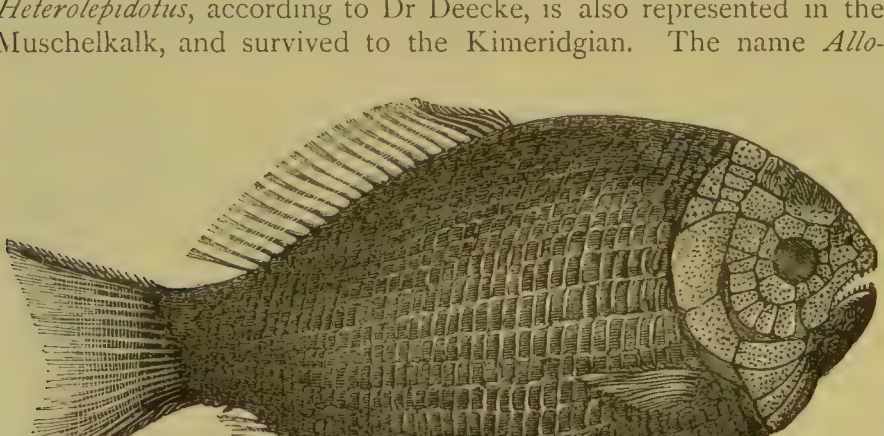


Fig. 922.—*Dapedius pholidotus*; from the Upper Lias of Würtemberg. Reduced.

lepidotus is applied to allied types also represented in the Muschelkalk. *Dapedius* (fig. 922), in which *Æchmodus* may be included, comprises a number of medium-sized fishes with broadly ovate bodies, ranging in Europe from the Keuper to the Lower Jurassic, but also occurring in the Kota beds of the Indian Gondwanas, which are somewhat higher than the Maleri beds from which *Ceratodus* is obtained. The dorsal and anal fins have elongated bases, and the inequality between the upper and lower lobes of the scaled part of

the caudal fin is comparatively slight. In typical species the teeth are simple, while in others (on which *Æchmodus* was founded) they are forked at their summit; since, however, both types are occasionally found in a single species, they do not afford grounds for generic distinction. The so-called *Amblyurus* has been founded on crushed Liassic specimens of *Dapedius*. Allied forms are *Pleurolepis* and *Homœolepis*, from the Upper Lias of Würtemberg. In *Tetragonolepis*, of the European Lias and the Kota beds of the Indian Gondwanas, the body resembles that of the type genus, but the form of the dorsal and anal fins is different, the caudal fin is nearly symmetrical, and the vertebral centra develop rings of bone; all these characters approximating to the next family, in which Sir P. Egerton placed both this and the following genus. *Clithrolepis* is an allied genus typically from the Wianumattu and Hawkesbury beds of New South Wales, but also occurring in the Stormberg beds of the South African Karoo system, and not improbably in the Indian Kota beds; all these strata being of approximately equivalent age.

Family Pycnodontidæ.—The Pycnodonts form a compact group, ranging from the Lias to the Eocene, in regard to the serial

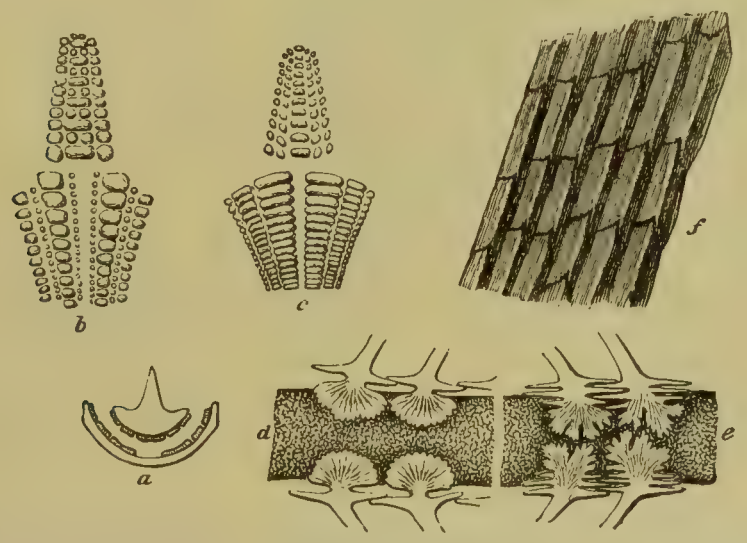


Fig. 923.—Dentition, scales, and vertebral column of Pycnodonts: *a*, Jaws, and *b*, vomerine and mandibular teeth of *Microdon*; *c*, Do. of *Cœlodus*; *d*, Vertebral column of *Palæobalistum*; *e*, Do. of *Pycnodus*; *f*, Scales of *Gyrodus*. The dentition is greatly reduced.

position of which very divergent views have been entertained. Dr Traquair is, however, disposed to regard them as specialised forms connected with the *Dapediidæ* and *Lepidotidæ*, and they are accordingly here placed between those families. This family has been recorded from Europe, Asia Minor, North America, and Australia, and presents the following characteristics. The body is of a rhomb-

oidal shape, presenting a striking resemblance in this respect to the *Platysomidæ;* the caudal fin is of a completely masked heterocercal type, and there are no fulcra to the fins. The notochord is persistent, but the neural arches and ribs are ossified, and in the later forms the heads of the latter (fig. 923) are enlarged, so as to simulate portions of vertebral centra. The premaxillæ are toothless; the conjoint palatines and vomer form a triangular bone (fig. 923), carrying five longitudinal rows of oval or round molariform teeth, while in the mandible the dentary bones, which form the extremity of the symphysis, have two or four chisel-like teeth, and the splenials are enlarged and carry on either side from three to five or more rows of molariform teeth (fig. 923) opposed to those of the former. Commencing with the typical genus *Pycnodus*, we find this, as now defined, restricted in Europe to the Lower Eocene of Sheppey and the Middle Eocene of Monte Bolca in Italy. There are only three rows of teeth on either side of the mandible, of which the innermost is the largest; while on the vomer the teeth of the three inner rows are round, and those of the two outer rows are larger and oval. Other characters are found in the position of the orbit, the large size of the mouth, and the superiority in the length of the dorsal as compared with the anal fin. A fish from the Cretaceous of Brazil has been referred by Professor Cope to this genus. The allied *Palæobalistum* (fig. 923, *d*), in which all the upper teeth are subequal, occurs in the Chalk of the Lebanon, the Cretaceous Pisolite of Mont Aimé in France, and also in the Middle Eocene of Monte Bolca. The greater number of the Cretaceous forms are, however, referable to the genus *Acrotemnus Cœlodus*,[1] which comprises some species attaining

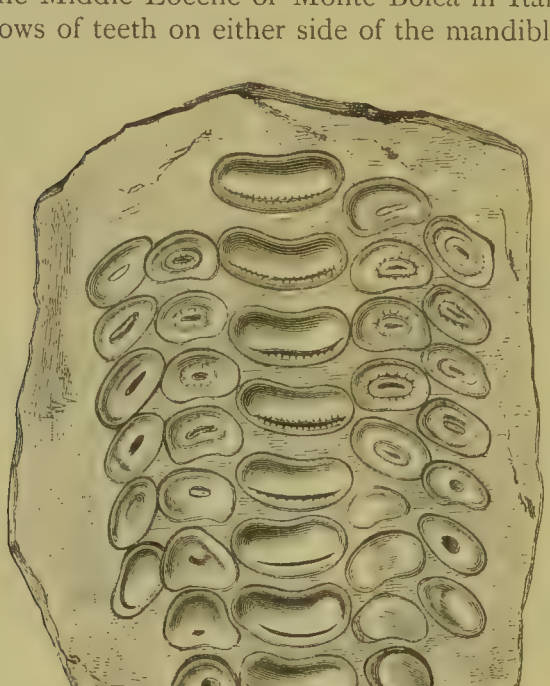


Fig. 924.—Vomer of *Acrotemnus gyrodoides;* from the English Cretaceous. (After Egerton.)

[1] The name *Cœlodus* being preoccupied by *Cœlodon*, the term *Acrotemnus*, proposed by Agassiz for detached teeth, is adopted.

a large size. The vomerine teeth (fig. 924) of the middle row are elliptical, and much larger than either of the others, while there are usually three rows on either side of the mandible, although these are occasionally increased to four. The dorsal fin extends in advance of the anal. This genus ranges from the Gault to the Chalk, and is widely spread through Europe. In *Mesodon* we have a genus ranging from the English Lias to the Lower Kimeridgian of Bavaria, and not improbably also represented in the Lower Greensand. Here the vomerine teeth of the middle row are larger than the teeth of the other rows, which are exceedingly small, and in the outermost line have a wart-like surface. Allied genera are *Mesturus* and *Athrodon* from the Kimeridgian of the Continent.

Stemmatodus (fig. 925), which comprises two small species from the Lower Cretaceous of Italy, is characterised by the great length

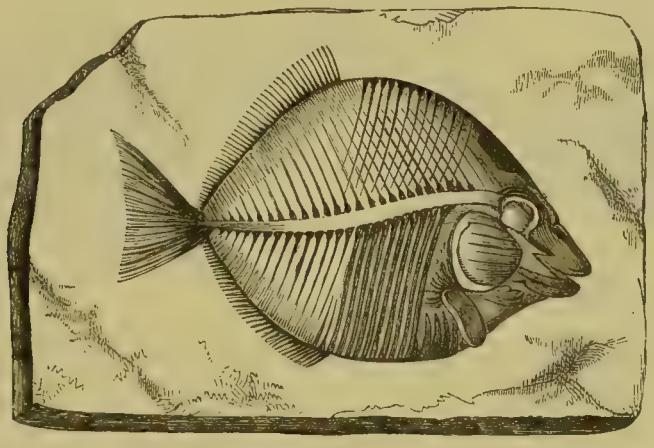


Fig. 925.—*Stemmatodus rhombus;* from the Lower Cretaceous of Italy.

of the dorsal and anal fins, and also by the concave surfaces of the molariform teeth, which are of subequal size. *Microdon* is another allied genus, ranging in Europe from the Kimeridge to the Purbeck. The arrangement of the teeth, and the peculiar structure of the heads of the ribs are shown in fig. 923. In *Gyrodus* we seem to have the most specialised members of the entire family, all of them being characterised by the sculptured crowns of the molariform teeth. The vomer is very narrow, and has the teeth subcircular, those of the middle row being much the largest; while in the mandible there are four rows on either side, of which the first and third are the larger. This genus is especially abundant in the Lower Kimeridgian lithographic limestone of Bavaria, but it also ranges upwards into the Chalk of Sussex, and downwards into the Lower Jurassic Stonesfield Slate. Finally, *Coccodus* is founded on an imperfect specimen from the Chalk of the Lebanon really belonging

to this family, but which has been referred to the Teleostean Siluroids.

Family Lepidotidæ (Sphærodontidæ).—In the *Lepidotidæ* the body is more or less fusiform, the upper scaled portion of the tail is longer than the lower, and the fulcra of the fins are well developed. The palatine, vomer, maxilla, and dentary carry rows of knob-like teeth (fig. 926), while the premaxilla is furnished with teeth of a chisel-like form. The type genus *Lepidotus* (fig. 926), with which *Sphærodus* is in great part identical, has a wide distribution both in time and space. Thus, in Europe it ranges from the Muschelkalk, or Middle Trias (where its scales have been described under the names of *Dactylolepis* and *Thollodus*) to the Chalk, and it also occurs in the Kota group of India, and the Cretaceous of Brazil and of North America. The large button-like teeth of *L. maximus* are abundant in the Kimeridge Clay, and specimens have been

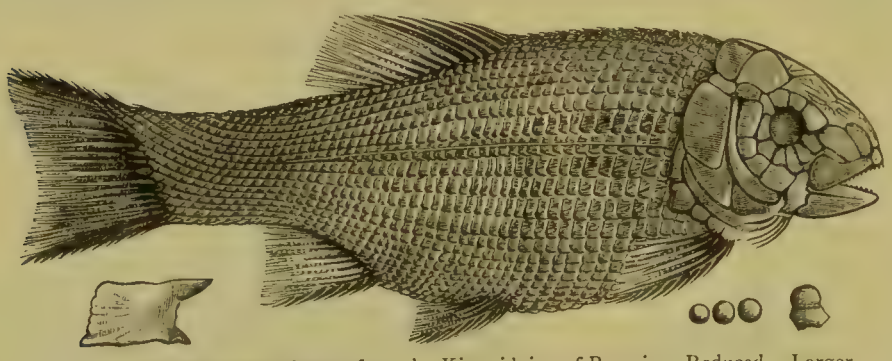


Fig. 926.—*Lepidotus maximus*; from the Kimeridgian of Bavaria. Reduced. Larger views of teeth and a scale are given in the corners.

found comprising nearly the whole palate, and exhibiting the curious manner in which the replacing teeth gradually turn over as they come into use. The names *Nephrotus*, *Cenerodus*, *Omphælodus*, *Hemilopus*, and *Asterodon*, have been applied to molariform and chisel-like teeth belonging to members of this family from the Trias of Silesia and Thuringia; while teeth of the latter type from the bone-bed of the same period, in both Würtemberg and England, described under the name of *Sargodon*, should, perhaps, be likewise placed here; and *Neorhombolepis*, of the English Chalk, appears to be an allied form.

Family Eugnathidæ (Saurodontidæ). — The body in this family is long and slender; the snout short; the fins have fulcra, the caudal being of a partially or completely masked heterocercal type; the vertebral centra may be either imperfectly or fully ossified, and the teeth are pointed. The range in time of this family extends from the Upper Trias to the Neocomian of Europe, but may, perhaps, also include the Chalk. In the typical group we have *Eu-*

gnathus ranging from the Keuper to the Kimeridgian, while in the Lias we find *Platysiagum* and *Ptycholepis*, and *Pholidopleurus* and *Peltopleurus* in the Keuper. A second group is represented by *Pleuropholis*, of the Kimeridgian of Bavaria, and also by *Thoracopterus* and *Pterygopterus* of the Keuper, the latter being distinguished by the absence of the pelvic fins. The genus *Pholidophorus* includes small Fishes somewhat resembling a Carp in form, which range from the Muschelkalk to the Purbeck. A fish from the Muschelkalk, originally described as *Pholidophorus porro*, has been made the type of the genus *Prohalecites*, on account of peculiar features in its squamation. Larger forms are ranked under the genera *Isopholis* of the Lias and Kimeridgian, and *Ophiopsis*, which extends from the Lias to the Purbeck. Of the remaining genera we have *Eusemius* and *Propterus* in the Kimeridgian of Bavaria; *Notagogus* from the latter deposits, and also in the Lower Greensand of Italy; *Histionotus* in the Bavarian Kimeridgian and the English Purbeck; *Macrosemius* ranging from the Stonesfield Slate to the Kimeridgian of Bavaria; and *Legnonotus* from the English Lias. *Lophiostomus*, from the Chalk of Sussex, may perhaps be placed here, although its skull approximates to that of *Amia*. The scales are pitted, and have a pectinated posterior border.

Family Aspidorhynchidæ (Rhynchodontidæ).—In this family the body is much elongated, and covered with scales of unequal

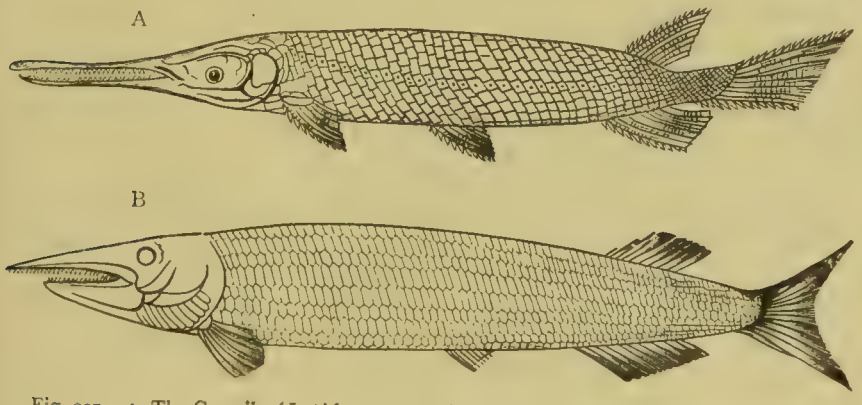


Fig. 927.—A, The Gar-pike (*Lepidosteus osseus*). Recent. North America. B, *Aspidorhynchus*; from the Jurassic. Both much reduced.

sizes; the skull is produced into a short rostrum; the caudal fin is of the masked heterocercal type; the fins carry fulcra; the vertebræ have ossified rings; and the teeth are either blunt or sharp. This family is represented only by the Mesozoic genera *Aspidorhynchus* and *Belonostomus*, in both of which the dorsal fin is placed above the anal. In the former (fig. 927, B), which ranges from the Lias to

the Purbeck, the length of the upper jaw exceeds that of the lower, and in advance of the mandibular symphysis there is a predentary bone (not shown in the figure) apparently corresponding to the one found in certain Dinosaurs. In *Belonostomus*, which, as now restricted, ranges from the Lower Kimeridgian of Bavaria to the Chalk, the predentary bone is so much elongated as to make the upper and lower jaws of nearly equal length, and the predentary carries a median row of large conical teeth, flanked by two rows of minute teeth; the teeth of the normal bones of the jaws having mammilated crowns adapted for crushing.

Family Belonorhynchidæ.—This family name has been proposed by Mr S. Woodward for the remarkable genus *Belonorhynchus*, typically occurring in the Upper Trias of Carinthia, but also found in the Lower Lias of Dorsetshire, where the specimens had been originally referred to *Belonostomus*. According to the writer quoted, *Belonorhynchus* was allied to the latter genus, having a similar long and slender body, with the same general position and structure of the fins, and probably furnished with a predentary bone. The fulcra of the fins were, however, either absent or very minute; and, with the exception of a median dorsal and ventral series of scutes, and another series on the lateral line, the body was naked. The imperfectly known *Saurichthys*, from the Rhætic of Bristol, is a closely allied, if not generically identical, type. Specimens of the upper jaw show that (as in *Belonorhynchus*) the bone was covered with fine tubercles, and that the maxillæ gave off horizontal palatal plates, like those found in Amphibians and Reptiles.

Family Lepidosteidæ.—The Gar-pikes of the genus *Lepidosteus* (fig. 927, A), inhabiting the freshwaters of Northern and Central America and Cuba, agree with the *Aspidorhynchidæ* in the general contour of the body and the arrangement of the fins; but the rostrum of the skull is much longer, and the tail distinctly heterocercal. The scales are lozenge-shaped. The existing genus appears to be represented in the Lower Eocene of France by a species (*L. Maximiliani*) formerly referred to *Lepidotus;* and it may also occur in the Upper Eocene (Oligocene), where a species described under the name of *Naisia* has been referred to it. In North America we have also *Pneumatosteus*, from the Miocene, and *Clastes*, from the Lower Eocene, both being freshwater forms, and the latter also occurring in the Eocene of Rheims.

Suborder 7. Amioidea.—According to Dr Traquair's classification, the last and most specialised suborder of the Ganoids is typically represented by the existing *Amia* and a series of Mesozoic genera approximating more or less closely to the Teleostei. In these forms the paired fins are non-lobate; the infraclavicular bone is absent; the opercular are Teleostean; the branchiostegals have a

median jugular plate; the vertebræ are more or less completely ossified; the tail is masked heterocercal; and the scales are thin and usually cycloidal. In all cases the teeth are small and pointed. It is probable, indeed, that in the Mesozoic representatives of this group we have forms closely allied to the ancestors of the Teleostei, and it is more than likely that future discoveries will show a complete passage between the Ganoids, as represented by this suborder, and the Teleosteans.

Family Pachycormidæ (Microlepidoti).—According to Professor Zittel, *Pachycormus* and its allies should be placed in this suborder, although other writers have regarded them as more nearly related to the *Dapediidæ*. In these forms the scales, although thin and imbricating, are subrhomboidal, and the vertebral column is very incompletely ossified. The chief genera, which are European, include *Pachycormus*, ranging from the Lias to the Oxford Clay (Middle Jurassic); *Endactis*, from the Lower Lias; *Euthynotus*, of the same horizon; and *Hypsicormus*, *Sauropsis*, and *Agassizia*, of the Lower Kimeridgian of Bavaria.

Family Caturidæ.—The Caturoids are a family of Salmon-shaped fishes, varying greatly in size, and ranging in time from the Lias to the Chalk, but especially common in the Kimeridgian lithographic limestones. The vertebral column may be either very imperfectly or completely ossified, the tail is more or less deeply forked, and the fins have fulcra. *Caturus* itself comprises a number of species, some of which are of large size, and two of which are represented in figs. 928, 928 *bis*. The scales are very like those of the Teleosteans,

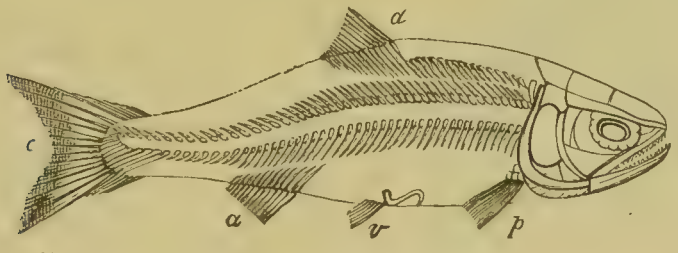


Fig. 928.—Skeleton of *Caturus furcatus*; from the Kimeridgian of Bavaria. Reduced. *p*, Pectoral; *v*, Pelvic; *a*, Anal; *c*, Caudal; *d*, Dorsal fin.

but still retain the Ganoid character of an inferior layer of bone and an upper one of enamel. The dorsal fin is placed immediately above the pelvic. This genus ranges from the Lias to the Kimeridgian, *C. maximus* attaining a length of three feet. *Strobilodus*, from the Kimeridgian of England and the Continent, is a closely allied if not identical genus. Other genera are *Isocolum*, from the Dorsetshire Lower Lias; and the Jurassic *Liodesmus*, *Eurycormus*, *Oligopleurus*, *Œnoscopus* (*Attakeopsis*), *Macrorhipis*, and *Æthalion*. *Oligopleurus*

has the dorsal fin placed behind the pelvic; and in this and several of the other genera the vertebræ consist of the upper and lower horse-shoe-shaped elements mentioned in the preliminary notice of the order.

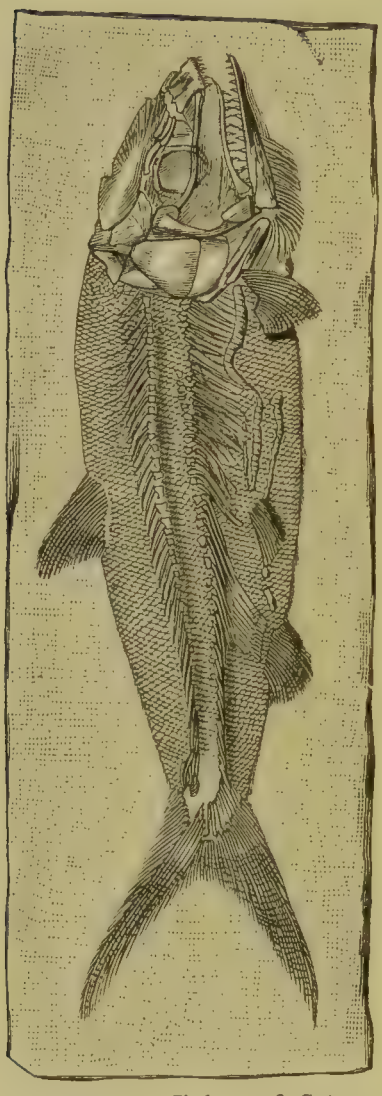


Fig. 928 *bis.* — Skeleton of *Caturus elongatus*; from the Kimeridgian of France. One-half natural size. (After Zittel.)

Family Leptolepididæ.—Of striking similarity in external contour to the Caturoids is the genus *Leptolepis* (fig. 929), which is placed by Dr Günther next to that family, although some palæontologists regard it as a Teleostean. The vertebral column is fully ossified, and the fins are without fulcra. In this genus, which ranges from the Lias to the Kimeridgian, the dorsal fin is placed immediately over the pelvic; but in *Thrissops*, of the Kimeridgian, it is above the anal. In external characters these Fishes cannot be distinguished from Teleosteans; and it is probable that they are intimately connected with that order, even if they should not be placed in it.

Family Amiidæ.—In the Amioids the vertebral column is fully ossified, and in the caudal region has a series of centra bearing the neural and hæmal arches, which alternate with intercentra devoid of such appendages. Fulcra may or not be present; and the caudal fin is convex, with the extremity of the vertebral column bent sharply up into the upper lobe. In *Megalurus*, of the Purbeck and Kimeridgian, fulcra are present, and the dorsal fin is short, and does not extend in advance of the pelvic. *Lophiurus*, from the same horizon, and *Opsigonus* and *Amiopsis*, of the Lower Chalk, are other genera, of which the first two are nearly related to *Megalurus*. The existing *Amia*, of the freshwaters of the southern United States, has no fulcra, and the dorsal fin occupies three-quarters of the length of the body. It appears probable that this genus is represented in the Upper Eocene (Lower Oligocene) and the Lower Miocene of the Continent, where its remains have been

described under the names of *Cyclurus* and *Notæus;* and it also occurs in the Eocene of Colorado and Wyoming, where it has been described as *Protamia* and *Hypamia.* The Eocenes of the latter district and of Rheims have also yielded the allied *Pappichthys*,

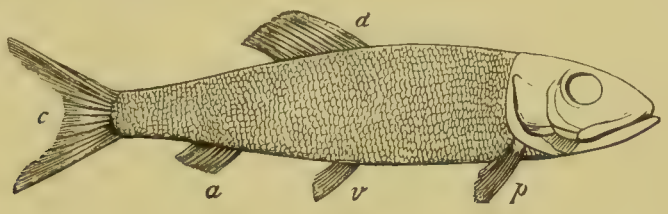


Fig. 929.—*Leptolepis sprattiformis;* from the Kimeridgian of Bohemia. Letters as in fig. 928.

in which there is but a single row of teeth; and members of this family may occur in the Chalk of the Lebanon.

Incertæ Sedis.—The remarkable genus *Dorypterus*, of the Permian of Hesse and Durham, may be conveniently noticed here, since its position is very problematical. In this remarkable fish the body is shaped somewhat like that of a Sunfish, and the anterior part of the dorsal fin is taller than the whole depth of the body. There are, moreover, the Ganoid characters of fulcra to the fins, and the notochordal condition of the vertebral column; but, on the other hand, there are no ganoid scales, and the pelvic fins are placed in advance of the pectorals, as in some of the Teleostei. On account of this curious combination of characters, Professor Cope has proposed to make *Dorypterus* the type of a special order, the Dorycopteri, with the family *Dorypteridæ.*

CHAPTER L.

CLASS PISCES—continued.

Order Teleostei.

Order VI. Teleostei. — The last, and in many respects the most highly organised, order of Fishes is the Teleostei, which includes the greater number of existing forms, and (unless some of the genera here placed in the Amioidea belong to it) does not date back beyond the Cretaceous. The Teleostei are in all probability descended from the Ganoids, and occupy in the class a somewhat analogous position to that held by the Squamata among the Reptiles and the Passeres among Birds; all traces of Amphibian affinities having been entirely lost in this order.

It is impossible to give a definition of the order by which it can be sharply separated from the Ganoids, but the following are its most characteristic features from a palæontological point of view. The body is usually covered with thin elastic, cycloid, or ctenoid scales (figs. 832, 833); but bony scutes or ganoid scales are occasionally present. The whole of the endoskeleton is well ossified; and the gills are freely suspended in a gill-cavity covered by a well-developed operculum (fig. 930). The caudal fin of the adult is of that completely masked heterocercal type usually termed homocercal (fig. 931). The pelvic fins may be either abdominal

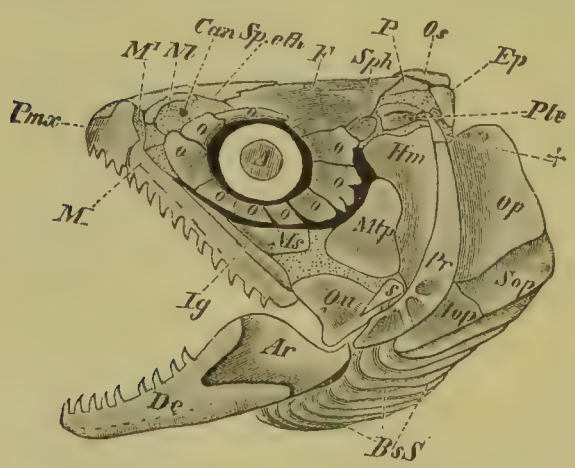


Fig. 930.—Skull of Trout (*Salmo*). Reduced. Letters as in fig. 843, p. 917.

or placed in advance of the pectorals. The fin-rays may or may not be articulated; and there are never fulcra on the fins. There are two pairs of nasal openings on the top of the head. Other characters are found in the soft parts which are not usually available in the case of fossils.

It may further be observed that Teleosteans agree with Ganoids in the hyostylic structure of the skull, and that cranial bones and a secondary pectoral girdle (fig. 844) are always developed. The arrangement of the cranial bones in a typical Teleostean is shown in fig. 930, where it will be seen that the preopercular (*Pr*) does not

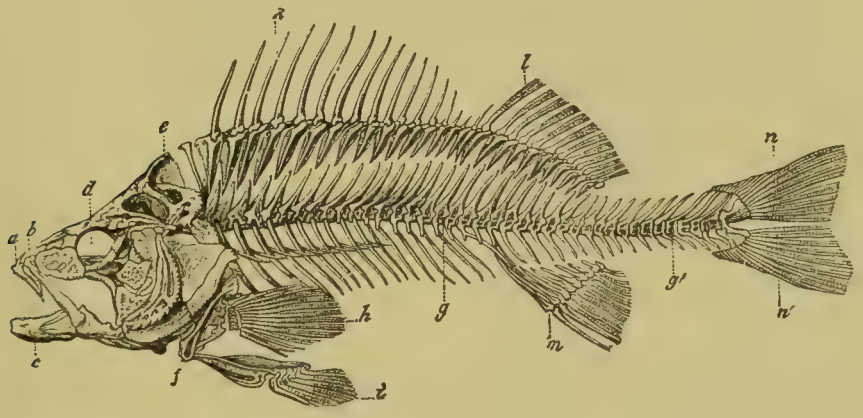


Fig. 931.—Skeleton of the Perch (*Perca fluviatilis*). Reduced. Letters as in fig. 836, p. 913.

extend on to the face as it does in some Ganoids. In certain forms, however (*Siluridæ*), the cranium develops large bony plates, articulating with others in the cervico-dorsal region, and presenting a striking resemblance to some of the cartilaginous Ganoids. In the same group strong spines, articulating with the underlying bones, are developed in the pectoral and dorsal fins; while the Salmonoids, many Siluroids, and others develop behind the rayed dorsal an additional fin without rays, to which the name *adipose* or *fatty fin* is applied.

According to Dr Günther's classification, the Teleostei are divided into six suborders, but other writers would group the last five of these together under the name of Physoclysti, as of equivalent value to the first, or Physostomi. The former arrangement will be followed here, but only such families as are of importance to the palæontologist can be noticed.

Suborder 1. Physostomi.—In this suborder the swim-bladder, when present, is connected by a duct with the pharynx; the pelvic fins are generally abdominal in position, and have no spine; while all the fin-rays are articulated, but sometimes only the first rays of the dorsal and pectoral fins are ossified. This suborder comprises

the most generalised Teleosteans, and those most nearly connected with the bony Ganoids.

Family Salmonidæ.—The members of this and the next family are so intimately connected by fossil forms, that it is very difficult to draw any distinction between them, and it has accordingly been proposed by some writers that they should be united under the name *Halecidæ*. The fossil genus *Halec* is, however, very imperfectly known, and if it be eventually found advisable to merge the two families, it would seem preferable to employ the name *Salmonidæ* in this wider sense. Existing Salmonoids are characterised by the presence of an adipose dorsal fin, and by the premaxilla and maxilla forming the borders of the mouth, and both bearing teeth. There are no scales on the head, and no barbels to the mouth. Recent Salmonoids are either marine, or inhabitants of the freshwaters of the Northern Hemisphere. Remains of the existing marine genus *Osmerus* (Smelt) occur in the Upper Greensand of Germany, the Lower Eocene of Glarus, in Switzerland, and the Miocene of Licata, in Sicily; while nodules of unknown age found in Greenland and Canada enclose a species of *Mallotus* indistinguishable from the existing *M. villosus* of the former region. As forms connecting the Salmonoids with the Clupeoids we may notice *Aulolepis*, *Acrognathus*, and *Osmeroides*, from the English Chalk. The first has a rounded body and a depressed head, with minute teeth, and the pelvic fins abdominal. In the second the orbits are of enormous dimensions, and the teeth extremely minute. The third genus (fig. 932) is also abundantly represented in the Chalk of the Lebanon, and appears to have no adipose fin; its skeleton in many

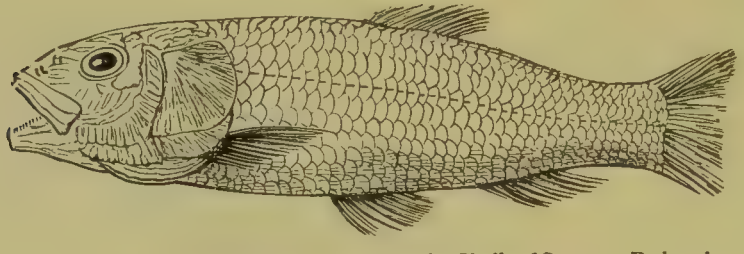


Fig. 932.—*Osmeroides lewesiensis*; from the Chalk of Sussex. Reduced.

respects resembles that of the Clupeoids, but the ribs have not the peculiar structure of that group. *Sardinius*, from the Chalk of the Lebanon, and *Sardinoides* from the same locality, and also from the Chalk of Westphalia, are more or less closely allied forms; while *Opisthopteryx*, of the Lebanon Chalk, may also be provisionally placed here.

Family Clupeidæ.—The existing members of the Clupeoid or Herring family differ from the Salmonoids by the absence of the

adipose fin, and the presence of peculiar dermal ossifications at the ends of the ribs, which form bony plates on the sides of the thorax. All the numerous forms are marine, and usually occur near the coasts. The type genus *Clupea* (Herring) occurs in the Miocene of Würtemberg, the Upper Eocene of the Isle of Wight, the Eocene of Wyoming and Glarus, and the Chalk of the Lebanon. The

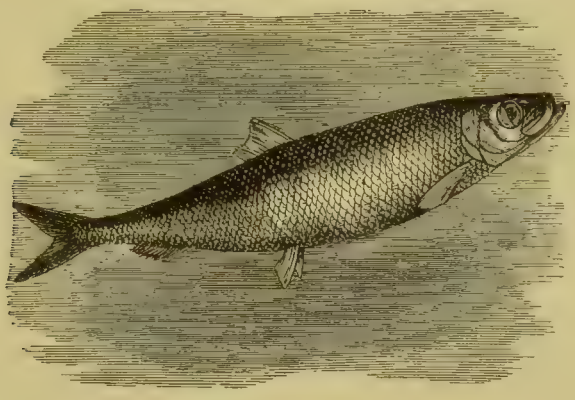


Fig. 933.—The Common Herring (*Clupea harengus*). Reduced.

common existing Herring is shown in fig. 933. The Lebanon Chalk has also yielded a species of the living genus *Engraulis*; and the extinct genera *Scombroclupea*, *Leptosomus*,[1] *Chirocentrites* (also in Westphalia), and *Spaniodon*, which are more or less closely allied to existing types. In the Eocene of the Continent we have representatives of the existing genera *Engraulis* (Anchovy) and *Chanos*, and the extinct *Platinx*, *Cœlogaster*, and *Crossognathus*—the latter being allied to the existing *Megalops*.

In this place we may conveniently notice a number of extinct genera more or less allied to the Clupeoids, but of which the family

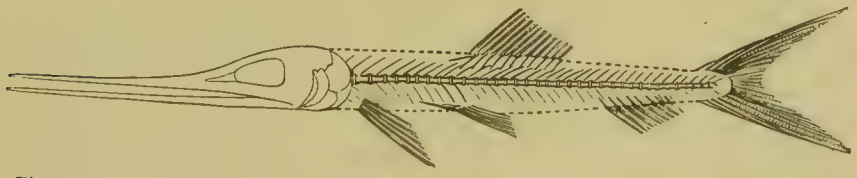


Fig. 934.—Skeleton of *Rhinellus furcatus*; from the Cretaceous of the Lebanon. Reduced. (After Pictet and Humbert.)

position is in some instances uncertain, and some of which retain indications of marked affinities to the higher Ganoids. One of the most remarkable of these is *Rhinellus* (fig. 934), in which the skull

[1] Preoccupied by *Leptosoma*.

is produced into a rostrum, occasionally equal in length to the entire body; this genus occurs in the Chalk of the Lebanon, and is considered to show affinity with *Opisthopteryx*. Another group seems to be related to the existing Clupeoid genus *Elops*, but also presents characters connecting it with the American freshwater family *Characinidæ*. Among these we may notice *Rhacolepis*, from the Cretaceous of Brazil; and in Europe *Elopides*, from the Lower Eocene of Glarus; *Elopopsis*, from the Cretaceous of Bohemia and Istria; *Hemielopopsis*, in which the borders of the mouth appear to have been devoid of teeth, from that of Lesina, on the Dalmatian coast; and *Protelopis*, of the Bohemian Cretaceous, characterised by the short jaws and the presence of crushing-teeth on the palate. *Thrissopater*, again, from the Folkestone Gault, differs from the modern Elopine type by its compressed body; while *Halec*, of the European Chalk, is still very imperfectly known. *Alosa*, of the

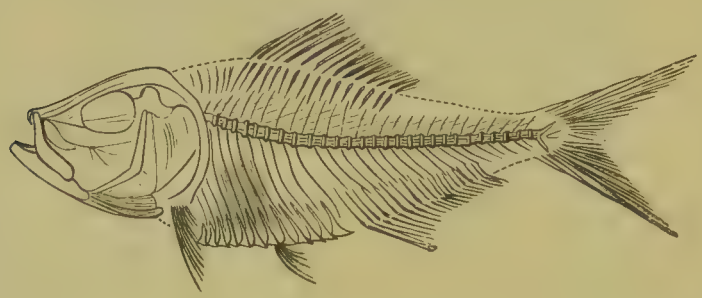


Fig. 935.—Skeleton of *Diplomystus brevissimus*; from the Chalk of the Lebanon.

Eocene of Algeria, and *Diplomystus* (fig. 935), originally described from the Eocene of Wyoming, but subsequently found in the Cretaceous of Brazil and of the Lebanon, are allied forms. The latter genus has a series of dorsal scutes, which are very characteristic. *Hemitrichias*, from the Tertiary of Northern Italy, differs from all existing Clupeoids in having two dorsal fins.

Family Protosphyrænidæ.—With this family we come to the first of a group comprising several families of extinct marine Fishes characterised by their large spear-like teeth, and hence termed Saurodonts. They should evidently be placed near the Clupeoids, although their division into families must be regarded as provisional. The present family is characterised by the production of the ethmoid in advance of the maxilla, to form a long cylindrical rostrum; by the loose connection of the premaxillæ with the maxillæ; and probably also by the complexity of the mandible. The teeth were implanted in distinct sockets. The type genus *Protosphyræna* (*Erisichthe*) occurs in the Upper Cretaceous of both Europe and North America; and the large spear-like teeth of *P. ferox*, which

has the same distribution as the genus, are very common in the coprolitic beds of the Cambridge Greensand, and were for a long time referred to the American *Saurocephalus lanciformis*, which was once thought to be a Reptile. These teeth are compressed, and without marginal serrations. The fins were provided with large ribbed spines, which were at one time referred to the Selachian genus *Ptychodus*, and subsequently were made the type of another genus under the name of *Pelecopterus*.

Family Dercetidæ (Hoplopleuridæ).—The members of the second family of Saurodonts are characterised by their elongated shape, their powerful dentition, and the presence of several series of large triangular scutes along the sides of the body; there is but one dorsal fin in those forms in which the fins are known; the teeth are not implanted in sockets; and the skull is frequently produced into a rostrum. This family probably passes imperceptibly into the next.

The typical genus *Dercetis* (in which *Leptotrachelus* may be included) occurs in the Chalk of England, Bohemia, and the Lebanon, and also in the Upper Cretaceous of Westphalia; it is characterised by the length of the upper jaw exceeding that of the lower, and by the presence of five rows of scutes, of which the middle one bears the lateral line. The allied *Aspidopleurus* is confined to the Lebanon beds. Other members of this family are *Blochius*, from the Middle Eocene of Monte Bolca; *Plinthophorus*, of the English Chalk; *Pelagorhynchus*, from the Upper Cretaceous of Westphalia; and *Saurorhamphus*, from that of Istria. *Plinthophorus* has two rows of scutes, but is otherwise naked.

Family Enchodontidæ.—The genera which may be provisionally grouped under this name are distinguished by the moderate lateral compression of the body, which may be either naked or

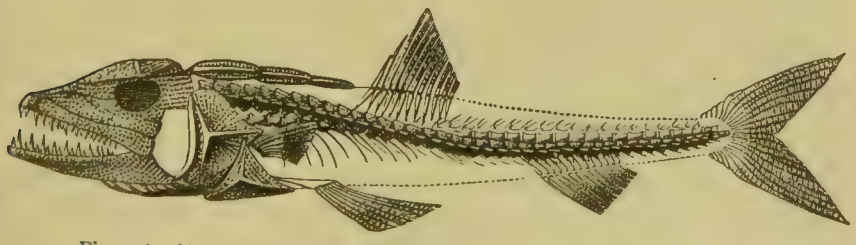


Fig. 936.—Skeleton of *Eurypholis Boissieri*; from the Chalk of the Lebanon. Reduced. (After Pictet and Humbert.)

covered with scutes, and by the elongated premaxillæ and maxillæ, which carry small teeth anchylosed (like those of the mandible) to the bone. A considerable portion of the maxilla is excluded from the margin of the jaw by the premaxilla; teeth occur on the pala-

tines and ectopterygoids; and the dentary bone of the mandible has one series of large teeth, with one or more inner rows of smaller ones. The type genus *Enchodus*, with which *Eurygnathus* of the Lebanon beds is identical, occurs in the Upper Cretaceous of Europe, North America, Brazil, and perhaps India. Closely allied to this genus is *Eurypholis* (fig. 936), of the Lebanon Chalk, which is merely distinguished by the presence of a few dermal scutes. *Cimolichthys*, from the Upper Cretaceous of Europe and the United States, and *Pomognathus* (*Phylactocephalus*), from the Chalk of Europe and the Lebanon, are nearly related genera, mainly distinguished by their dentition. Here also may be placed *Ischyrocephalus*, of the Upper Cretaceous of Westphalia, which may perhaps have had two dorsal fins, and appears to connect *Enchodus* with the *Dercetidæ*.

Family Pachyrhizodontidæ.—Allied to the preceding, but with the body more compressed, and covered with either scutes or scales, or both together, is a group of Fishes which may be provisionally placed in a distinct family. The premaxillæ and maxillæ are large, and carry powerful teeth, which may form one or more rows, and are set in incomplete sockets, and anchylosed to the bone; while the abdominal vertebræ are characterised by their longitudinal striation and the absence of deep pits. The type genus *Pachyrhizodus* (*Hypsodon* in part) ranges in Europe from the Chalk to the London Clay, and also occurs in the Cretaceous of North America; its teeth are so like those of Reptiles that a lower jaw was described as belonging to a species of *Mosasaurus*. *Empo*, of the North American Cretaceous, may be certainly placed in this family; in which we may also probably include *Stratodus*, of the Upper Cretaceous of both Europe and North America. An allied type, from the Lower Miocene of Belgium, has been described under the preoccupied name of *Amphodon*.

Family Saurocephalidæ (Saurodontidæ).—The last family of the Saurodonts are laterally compressed Fishes, in which the maxillæ and premaxillæ are large, and carry powerful teeth, which are usually implanted in distinct sockets. The dentary bone of the mandible has but a single row of similar teeth, and there are no teeth on the palatines and ectopterygoids. The vertebræ, with the exception of those of the cervical region, carry two deep grooves and pits on their lateral surfaces. The type genus *Saurocephalus* is represented in the Cretaceous of North America, and also by a single species in the topmost Cretaceous of Maastricht, in Holland; the teeth are subequal and closely approximated. *Ichthyodectes* and *Portheus* (fig. 937) also occur in the Upper Cretaceous of both Europe and North America; the latter, which extends down to the Gault, attaining large dimensions, and being characterised by the great crest in

the supraoccipital region, by the unequal size of the cylindrical or compressed teeth, and the presence of at least one large spine in the pectoral and pelvic fins. *Ichthyodectes* apparently differs mainly by its equal-sized teeth. Another genus is *Daptinus*, of the North American and English Cretaceous; the English species apparently connecting the typical American one with *Ichthyodectes*. *Saurodon* is known from the Upper Greensand of New Jersey; while we may

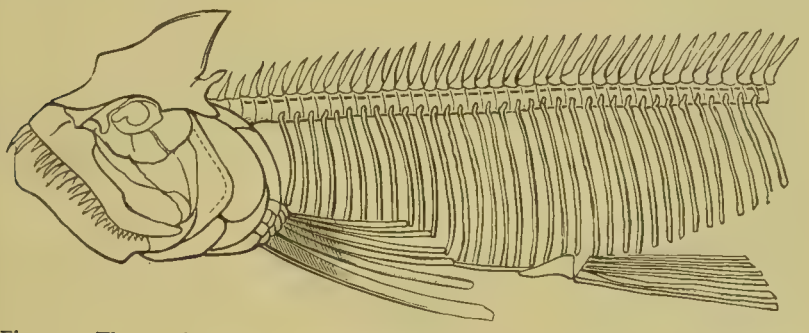


Fig. 937.—The anterior portion of the skeleton of *Portheus molossus*; from the Cretaceous of North America. Greatly reduced. (After Cope.)

provisionally place in this family the imperfectly known *Tomognathus*, of the English Chalk, in which the teeth were anchylosed to the jaws, without sockets, and had subcylindrical crowns enamelled superiorly.

As a probable Saurodont, of which the family position cannot be determined, may be mentioned *Gigantichthys* (*Titanichthys*), founded upon teeth of very large size, from the Cretaceous of Egypt.

Family Gonorhynchidæ.—We may now briefly mention five small existing families related to the Salmonoids and Clupeoids. The first of these is now represented only by a single species of *Gonorhynchus* found on the coasts of South Africa, Australia, and Japan. Closely allied, however, is *Notogoneus*, from the Eocene of Wyoming, which is mainly distinguished by its dentition.

Family Osteoglossidæ.—The second family is now represented by *Osteoglossum* of South Africa, Sumatra, and Queensland; the huge *Arapaima* of the Brazilian rivers; and *Heterotis* of several of those of South Africa; thus presenting a striking example of discontinuous distribution. The only known fossil is *Dapedoglossus*, of the Eocene of Wyoming; a feature in distribution analogous to the occurrence of the genus *Notogoneus* of the preceding family in the same locality.

Family Chirocentridæ.—The genus *Chirocentrus*, of the Indian Ocean, the sole existing member of this family, probably occurs in the Eocene of Sumatra. *Chiromystus*, from the Eocene of Brazil, may perhaps be referable to this family, although it is not certain

that it should not rather be placed in the allied American family *Hyodontidæ*.

Family Esocidæ.—The *Esocidæ* are now represented by the Pikes (*Esox*) of the rivers of the Northern Hemisphere. They are characterised by the margins of the upper jaws being formed by the premaxillæ and maxillæ; by the presence of small conical teeth on the palate; and the absence of an adipose fin, and the position of the dorsal in the hinder part of the body. Species of *Esox* occur in the Upper Miocene of Œningen in Switzerland, and the Pleistocene of Silesia; while the extinct *Sphenolepis*, of the Upper Eocene of Paris and the Eocene of Aix in Provence, characterised by its wedge-shaped scales, is considered to be allied. Recent writers also place in this family the marine *Istiæus* of the Chalk of Westphalia and the Lebanon, in which there is a long dorsal fin occupying the greater part of the back.

Family Scombresocidæ.—The members of this family mainly inhabit tropical and temperate seas, and are best known by the Garpike (*Belone*) and the Flying-fish (*Exocœtus*). The jaws are formed as in the last family; the dorsal fin is placed above the anal in the caudal region, and there is no adipose fin. *Belone* is found in the Miocene of Licata, in Sicily; while *Holosteus* of the Middle Eocene of Monte Bolca is an allied genus. The living genus *Exocœtus* is characterised by the enormous development of the pectoral fins, and was preceded in the Chalk of the Lebanon by the nearly related *Exocœtoides*.

Family Cyprinodontidæ.—The Cyprinodonts are mostly small, carp-like fishes, inhabiting the fresh, brackish, or salt waters of a considerable part of the world; and readily characterised by the presence of scales on the head, and the absence of barbels. Species of the type genus *Cyprinodon* (*Lebias*) occur in the Middle and Lower Miocene of the Continent, while the Œningen beds have yielded a species referred to the South American genus *Pœcilia*. A comparatively large Cyprinodont has been described from the Pliocene of India.

Family Cyprinidæ. — The important family of Carps is very numerously represented in the freshwaters of the Old World and North America. There are no scales on the head; the margin of the upper jaw is formed by the premaxillæ; there are no teeth in the jaws; there is no adipose fin; the lower pharyngeal bones carry one or more rows of teeth; and the mouth frequently has barbels. The body is more or less compressed, and is often comparatively deep. In the Miocene of the Continent we have representatives of the following genera now living in Europe—viz., *Cyprinus* (Carp), *Gobio* (Gudgeon), *Leuciscus* (Roach and Dace), *Tinca* (Tench), *Rhodeus*, which is mainly Asiatic, *Aspius*, and *Cobitis*. *Acanthopsis*,

now confined to India, is represented in the Miocene of Œningen and Puy-de-Dôme; the Oriental genera *Amblypharyngodon* and *Thynichthys* occur in the Eocene of Sumatra, while the names *Cyclurus*, *Hexapsephus*, and *Mylocyprinus* have been applied to North American Tertiary forms, which are probably more or less closely related to those now inhabiting the same region.

Family Scopelidæ.—The Scopeloids are marine fishes allied to the Carps (with which they agree in the structure of the jaws), in which the body may be naked, and there are neither barbels nor swim-bladder. They are represented in past epochs by *Hemisaurida*, of the Cretaceous of Istria, which is allied to the living *Saurus*, and *Parascopelus* and *Anapterus* from the Miocene of Sicily, of which the latter is related to *Paralepis* now found in the same region.

Family Siluridæ.—The Siluroids or Cat-fishes form a large family of freshwater fishes of not less importance than the Carps, inhabiting all temperate and tropical regions, and in some cases entering the sea. The skin is either naked or covered with bony scutes; there are always barbels, which frequently have a bony axis; the margin of the upper jaw is formed by the premaxillæ; there is no subopercular; and there may or may not be an adipose fin. The skull of the Siluroids is often remarkable for the great development of the supraoccipital (fig. 938), and the presence of dermal ossifications in the region of the neck, which spread over the nape, and articulate with the bones of the secondary pectoral girdle. The first and second interspinous bones of the neck frequently also develop a large bony buckler, behind which the long dorsal spine articulates by means of a ring with the first interspinal; and this spine can be fixed in an upright position by a curious mechanism connected with the second interspinal. The "helmet" of the nape may be continuous with the "buckler," and these bones, together with those of the cranium proper, are frequently ornamented with a granular sculpture. The pectoral fins frequently carry a spine as large as that of the dorsal. The pharyngeal teeth are generally knob-like.

From many points in which the Siluroids resemble the Placodermatous Ganoids, Professor Huxley has suggested that we may regard the latter as nearly related to the ancestors of the existing family. Siluroids are not definitely known before the Tertiary, although it has been suggested that *Telepholis*, from the Upper Cretaceous of Westphalia, may belong to this family. In Europe the earliest undoubted member of the family is known by an imperfect skull from the London Clay, which has received the name of *Bucklandium*; the affinities of this form are imperfectly known, but the skull seems to approximate to that of *Auchenoglanis* of the African rivers. In the Middle Eocene of Bracklesham, and the Upper

Eocene of Barton, we have Siluroids referred to the existing tropical genus *Arius;* the peculiar, somewhat heart-shaped, otoliths of these fishes being not uncommon in the Barton beds. It is interesting to notice the association in the English Eocene of Siluroids with Crocodiles and Trionychoid Chelonians; the three groups being found together at the present day in India and Africa. The Eocene of Sumatra has yielded remains of extinct species of the living Oriental genera *Pseudotropius* and *Bagarius;* the last-named genus being also represented in the Pliocene Siwaliks of India by the gigantic *B. Yarrelli*, now inhabiting the Ganges. The same beds have also yielded remains of *Clarias*, now found in both the Oriental and Ethiopian regions, of a species belonging to the genus *Heterobranchus* (fig. 938), which is now confined to the Nile, and not improbably also of *Chrysichthys* of tropical Africa. The existing *Macrones aor* of the Indian and Burmese rivers has also left its remains in the Siwaliks; while the characteristic Oriental genus *Rita* is likewise represented in the same deposits. Finally, of the widely-distributed genus *Arius*, which we have already mentioned from the English Eocene, there is evidence of two Siwalik species; one being apparently nearly allied to a large existing West African form. In the Eocene of North America there occurs the genus *Rhineastes*, which has vomerine teeth, and may be allied either to *Arius* or to *Pimelodus*, while spines from the same deposits have been referred to the latter genus.

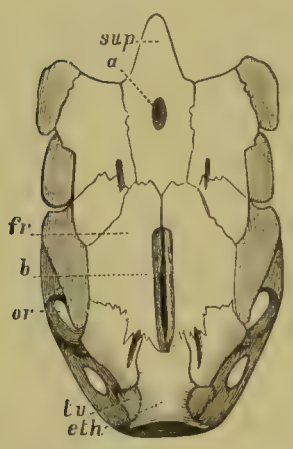


Fig. 938.—Upper view of the skull of *Heterobranchus intermedius;* from the Nile. One-half natural size. *a*, Supraoccipital, and *b*, Frontal vacuities; *eth*, Ethmoid; *fr*, Frontal; *or*, Orbit; *sup*, Supraoccipital; *tu*, Turbinal. The sculpture is omitted.

Family Muræniдæ.—The last family that we have to notice in this suborder is that of the Eels. In these fishes the body is greatly elongated, and either naked, or covered with rudimental scales; the toothed maxillæ form part of the border of the upper jaw, and there are no pelvic fins. Of the freshwater forms, *Anguilla* (Eel) ranges from the present date to the Chalk of the Lebanon, and is abundantly represented in the Miocene of Œningen and the Middle Eocene of Monte Bolca. The Marine forms, or Congers, are represented by species of the existing genus *Ophichthys* in the Monte Bolca beds; and by the extinct *Sphagebranchus* of the latter deposits, and *Rhynchorhinus* of the London Clay. Peculiar larval forms of the type known as *Leptocephali* occur in the Continental Tertiaries, some of which are probably referable to this family.

Suborder 2. Anacanthini.—In this and the four following suborders, together forming the Physoclysti of some writers, the swim-bladder (when present) has no connection with the pharynx, and the pelvic fins are nearly always thoracic or jugular in position—in the latter case being in advance of the pectorals. The present suborder is further characterised by the rays of the dorsal fin being soft and jointed, and the pelvic fin never abdominal.

Family Gadidæ.—In the Cod family the body (fig. 939) is symmetrical, and covered with small scales; there may be three dorsal

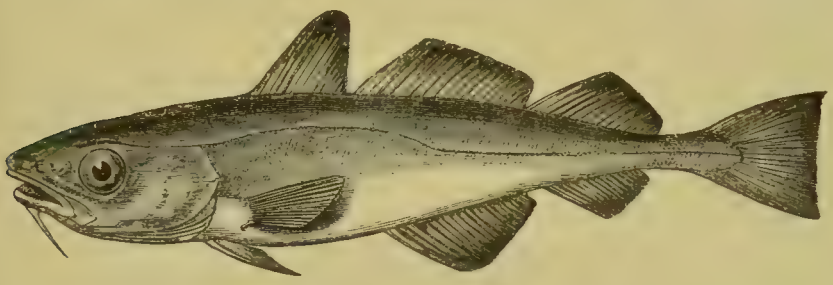


Fig. 939.—The Cod (*Gadus morrhua*). Reduced.

fins, and the pelvic fins are jugular. All the genera are marine, and the family is unknown before the Eocene. The extinct *Nemopteryx* and *Palæogadus* have been described from the Eocene of Glarus; while in the London Clay of Sheppey we have species

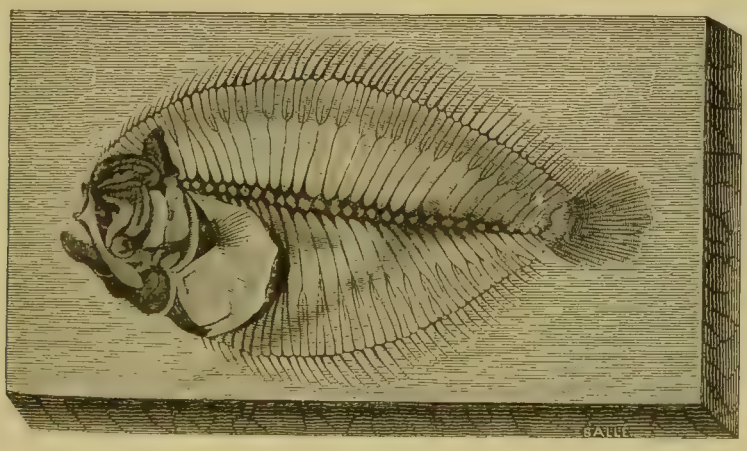


Fig. 940.—Skeleton of *Rhombus minimus*; from the Middle Eocene of Monte Bolca.

allied to *Gadus* (Cod), *Merluccius* (Hake), and *Physis*. Other Gadoids occur in the Miocene of Sicily.

Family Pleuronectidæ.—The Flat-fishes are characterised by the extreme lateral compression of the body (fig. 940), of which the

fore part and the head are not bilaterally symmetrical. They swim with one side upwards and the other downward, the head being twisted round so as to bring the two eyes upon that side which becomes the upper one, and which alone is coloured. There is no swim-bladder, and the dorsal and anal fins occupy almost the entire length of the body. Remains of a species of *Rhombus* or Turbot (fig. 940) are found in the Middle Eocene of Monte Bolca, and those of a *Solea* (Sole) in the Miocene of Würtemberg.

Suborder 3. Pharyngognathi. — In this small suborder a portion of the rays of the dorsal, anal, and pelvic fins is formed by non-articulated spines. The lower pharyngeal bones are united; and the swim-bladder has no duct.

Family Pomacentridæ.—Of this large family the only European fossil representative is *Odonteus* from the Middle Eocene of Monte Bolca, which is allied to the existing *Heliastes;* but Professor Cope thinks that *Priscacara* from the Eocene of North America may perhaps be referable to it, although vomerine teeth are present. All the members of this family have ctenoid scales.

Family Labridæ.—The Wrasses are a large family of littoral fishes most abundant in tropical and temperate regions, and characterised by their cycloid scales, the single dorsal fin, the thoracic position of the pelvic fins, and the absence of teeth on the palate. Many of them have the lips greatly thickened; and the pharyngeal bones bear molariform teeth. The existing genus *Labrus* is recorded from the Middle Eocene of Monte Bolca and the Miocene of Switzerland; while *Saurinichthys* of the Miocene of France appears allied to the living *Odacina*. *Protautaga* of the Eocene of North America is the ancestral form of the Black-fish (*Tautaga*) of the same country.

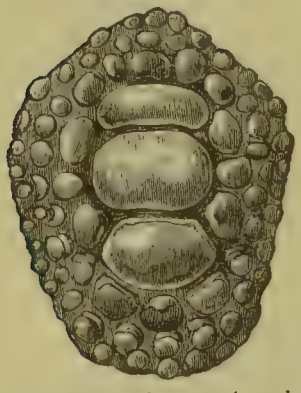


Fig. 941.—Pharyngeal teeth of *Phyllodus* from the London Clay.

Family Pharyngodopilidæ.—A number of extinct fishes more or less nearly allied to the Wrasses, but differing in several points very markedly from that family are regarded as forming a group by themselves. The type genus *Pharyngodopilus* (*Nummopalatus*) occurs in the French Miocene, and in the Tertiary of the Canaries; closely allied to which is *Phyllodus* from the Cretaceous of Germany and the London Clay of Sheppey, derived teeth being also found in the Suffolk Crag. The pharyngeal teeth of *Phyllodus* (fig. 941) are remarkable for their thin and leaf-like structure, and also for the rapid manner in which they are succeeded from below by fresh ones. The imperfectly known *Egertonia* from the Lower Eocene

of Sheppey, and *Platylæmus* from the Middle Eocene of Bracklesham, may be provisionally included in this family.

Family Chromidæ.—The Chromids are a family of small freshwater Fishes from Palestine, tropical Africa, and America; and also represented by one genus in India. The scales are usually ctenoid, the lateral line is interrupted, and the teeth of the jaws are very small. To this family is referred the large genus *Pycnosterinx* from the Cretaceous of the Lebanon; and with less certainty *Imogaster* of the same deposits.

Suborder 4. Acanthopterygii.—The Acanthopterygii form a very large series characterised by part of the rays of the dorsal, anal, and pelvic fins being non-articulated and forming strong spines. The lower pharyngeal bones are usually separate; and there is no duct to the swim-bladder. The scales are very generally ctenoid.

Family Ophiocephalidæ.—The *Ophiocephalidæ* are freshwater fishes, almost confined to the Oriental region, in which the long head and body are entirely covered with scales, and the dorsal and anal fins are long and devoid of spines. These fishes are in the habit of burying themselves in the mud during droughts. The type genus *Ophiocephalus* is represented in the Pliocene of India by species closely allied to, if not identical with some of those now inhabiting the same area.

Families Fistulariidæ and Centriscidæ.—The first of these families comprises the marine "Flute-mouths," characterised by the long body and the production of the anterior bones of the skull into a long tube, terminating in the mouth, and by the absence or small size of the scales. The existing genera *Fistularia* and *Aulostoma*, now found on the borders of the tropical Atlantic and Indian Oceans, are represented in the Eocene of Monte Bolca and Glarus; while *Auliscops*, now confined to the Pacific coast of North America, is found in the Eocene of Sumatra. Extinct genera from Monte Bolca are *Urosphen* and *Rhamphosus*—the former characterised by the wedge-like caudal fin, and the latter by a large spiny ray on the neck. A Fistularian, from the Lebanon Cretaceous, has been named *Solenognathus*, but the name is preoccupied. The *Centriscidæ*, which agree with the *Fistulariidæ* in the structure of the mouth, but differ in the form of the body, are known in a fossil state by a species of the living genus *Amphisile*, from Monte Bolca.

Family Mugilidæ.—This and the two next families include fishes characterised by the presence of two distinct dorsal fins, of which the first is either low, or has weak spines; and by the abdominal position of the pelvic fins, which have five rays and one spine. The Grey Mullets inhabit the coasts of tropical and temperate seas, and have cycloid scales with no lateral line. The recent genus *Mugil* occurs in the Upper Eocene of Aix; and *Calamo-*

pleurus, of the European Chalk, with which the North American genus *Syllæmus* is probably identical, may be placed in this family.

Family Atherinidæ.—These fishes, which differ from the Mullets by the presence of an indistinct lateral line and the great number of the vertebræ, are represented in the Middle Eocene of Monte Bolca by two minute species of the existing genus *Atherina*, and also by the extinct *Mesogaster*.

Family Sphyrænidæ.—The Barracudas, in which the lateral line is continuous and the vertebræ are not numerous, are known at the present day only by *Sphyræna*, of which some species attain a length of eight feet. That genus occurs in the Middle Eocene of Monte Bolca, and has also been recorded from the Upper Cretaceous of the Lebanon; but it is probable that the latter form belongs to one of the Saurodont Physostomi. *Cladocyclus*, from the Upper Cretaceous of England and Brazil, is an extinct genus.

Family Blenniidæ.—The Blennies form one of four families of but little palæontological importance, in which there is a long dorsal fin, which may be entirely spinous; and the ventrals, if present, are either thoracic or jugular. It is probable that *Pterygocephalus*, from the Middle Eocene of Monte Bolca, should be referred to this family.

Family Gobiidæ.—The Gobies belong to another group of the suborder comprising two families, into the characters of which it will not be necessary to enter. They are represented in a fossil state by the existing genus *Gobius*, from the Monte Bolca Eocene, and the extinct *Chirothrix*, from the Upper Cretaceous of the Lebanon.

Family Dactylopteridæ (*Cataphracti*).—This and the next six families form a group of considerably more interest to the palæontologist than the preceding. They are collectively known as the Cottoscombriform section, and are characterised by the presence of spines in at least one of the fins; by the dorsal fins being either continuous or close together; by the spinous dorsal, when present, being short; and when the latter is absent by the length of the soft dorsal. The pelvic fins are always jugal or thoracic. In the present family the body is cylindrical and elongate, with a coat of bony scutes; the dentition is weak; and the pelvic fins are thoracic. *Petalopteryx*, from the Middle Eocene of Monte Bolca, is considered to be related to the existing *Dactylopterus*, in which the pectorals are lengthened to an enormous extent.

Family Cottidæ.—This family is best known by the freshwater Bull-heads (*Cottus*) and the marine Gurnards (*Trigla*). The body is more or less oblong; the dentition weak; the dorsal fin is usually divided, with the soft portion the larger; and the pelvic fins are

thoracic, and generally have five soft rays. *Cottus* itself occurs in the Upper Miocene of Œningen; while the Upper Eocene of Aix yields the extinct *Lepidocottus*, distinguished by its ctenoid scales. *Trigla* occurs in the European Tertiaries.

Family Trachinidæ.—This family comprises a number of genera of small marine Fishes distributed over the greater part of the world, in which the body is long and slender, and may or may not have scales. The dorsal fin may be either single or divided, but its soft portion is always much longer than the spinous. To this family may probably be referred the naked *Callipteryx*, from the Middle Eocene of Monte Bolca; while *Trachinopsis*, of the Upper Tertiary of Spain, is considered to be allied to the existing *Trachinus*—a third extinct genus being *Pseudoeliginus*, of the Sicilian Miocene.

Family Scombridæ.—The *Scombridæ*, typically represented by the Mackerels (*Scomber*), but also comprising other pelagic Fishes, are characterised by the oblong and scarcely compressed body, the well-developed dentition, the two dorsal fins, the general presence of finlets in the posterior part of the body, and the thoracic position of the pelvic fins, which have one spine and five rays. In the Miocene and Eocene of Europe, we meet with species of the existing genera *Scomber* (Mackerel), *Thynnus* (Tunny), and *Cybium*, one Lower Miocene species of the latter having been described under the name of *Scomberodon*. Curiously enough, the specialised genus *Echeneis* (Sucking-fishes) is found in the Lower Eocene of Glarus. *Dictyodus* (*Sphyrænodus*) is an extinct genus from the Lower Eocene of England and the Lower Miocene of Belgium, characterised by the strong development of its dentition, and its single row of conical palatine teeth. Other extinct genera are *Palimphyes* and *Isurus*, of the Lower Eocene of Glarus, and *Orcynus*, from the Middle Eocene of Monte Bolca. The existing *Pelamys* has been recorded from the Lower Miocene of Belgium.

Family Coryphænidæ.—Another pelagic family allied to the preceding is represented by the well-known Coryphænas, popularly known by the misnomer of Dolphins. The body is compressed; the teeth, if present, are small and conical; and there is a long undivided dorsal fin, without a distinct spinous portion. The existing genus *Mene* (*Gastrocnemus*) is found in the Middle Eocene of Monte Bolca; while the family is also represented by the extinct *Goniognathus*, of the London Clay.

Family Cyttidæ.—The Dories have the body very deep and much compressed, with the dorsal fin divided, and its spinous portion taller than the soft part, and the pelvic fins thoracic. They are represented by a species of the existing genus *Zeus*, in the Miocene of Sicily, and also by the extinct *Cyttoides*, of the Lower Eocene of Glarus.

Family Carangidæ.—Of great interest to the palæontologist are the so-called Horse-Mackerels, on account of the beautiful preservation of some of the fossil forms in the Middle Eocene of Monte Bolca. The body is more or less compressed, and may be oblong or deep, and either with or without scales. The dorsal fin, which



Fig. 942.—*Semiophorus velicans;* from the Middle Eocene of Monte Bolca. A, Anal; C, Caudal; D, Dorsal; P, Pectoral; V, Pelvic fins.

may be single or divided, has the spinous smaller than the soft part; and the pelvic fins, if present, are thoracic. One of the most remarkable extinct genera is *Semiophorus* (fig. 942), in which the dorsal fin is of enormous height, while the pelvic fins are also greatly produced. This genus is known only from the Monte Bolca Eocene. Other extinct Tertiary genera are *Pseudovomer*,

from the Miocene of Sicily; *Amphistium* and *Ductor*, from Monte Bolca; *Archæus* and *Plionemus*, from the Lower Eocene of Glarus; and *Æpichthys* and *Vomer*, from the Chalk of Istria. Among existing genera, *Platax* (fig. 943), popularly known as Sea-Bats, from the great height of the fins, occurs in the Red Crag, in the Monte

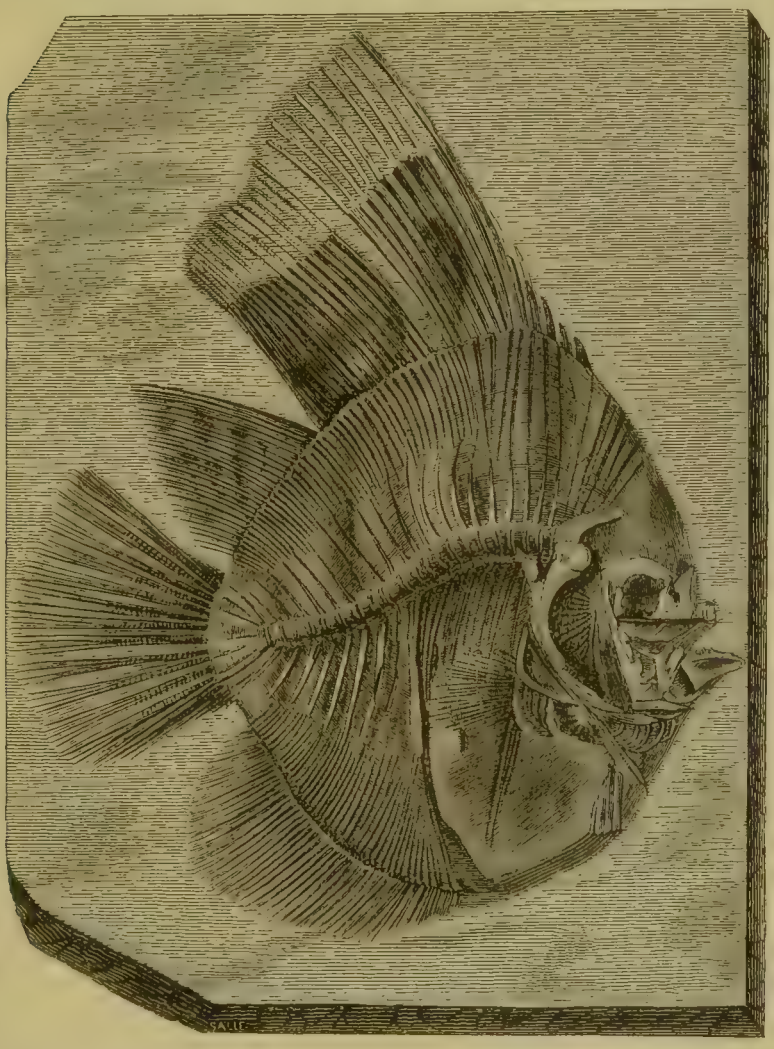


Fig 943.—*Platax altissimus*; from the Middle Eocene of Monte Bolca. Reduced.

Bolca Middle Eocene, and in the Chalk of the Lebanon and England. The dorsal fin is single, and the spinous portion is nearly entirely concealed, consisting only of from three to seven low spines; the jaws are remarkable for their excessive shortness. Other living genera found in the Monte Bolca beds are *Zanclus*,

Caranx (*Carangopsis*), *Argyriosus* (*Vomer*), *Lichia*, and *Trachynotus*; and *Equula*, from the Miocene of Sicily.

Family Acronuridæ.—The last family of the Cottoscombriform section comprises tropical marine Fishes, popularly known as Surgeons, which are readily recognised by the sharp spine bordering each side of the tail. The body is compressed, and oblong or ovate, with small scales; the front of the jaws has chisel-like or pointed teeth; and the dorsal fin is undivided, with the spinous portion less than the soft. This family is represented in a fossil state by species of the existing genera *Naseus* and *Acanthurus* from the Middle Eocene of Monte Bolca.

Family Trichiuridæ. — The next section of the suborder is represented by the existing Scabbard-fishes and the extinct *Palæorhynchidæ*. These Fishes are characterised by their elongated, compressed, or band-like bodies, furnished with long dorsal and anal fins, of which the former may be divided into a number of finlets, somewhat after the manner of the Ganoid genus *Polypterus*. All these fishes are marine, and are found in tropical and subtropical seas. Species of the existing genus *Lepidopus* (Scabbard-fish) occur in the Miocene of Sicily, while *Hemithyrsites* and *Trichiurichthys*, of the same deposits, are forms allied to the living *Thyrsites* and *Trichiurus*, but differing by having the body scaled. *Xiphopteryx* is another extinct genus from the European Eocene; while *Anenchylum*, of the Lower Eocene of Glarus, resembles *Lepidopus* except for the presence of some long rays in the pelvic fins, and the two are probably identical.

Family Palæorhynchidæ.—The members of this family differ from the last by the production of the jaws into a long rostrum, which is either edentulous or provided with very small teeth. The dorsal fin occupies the whole length of the body, and the anal is also elongated and reaches nearly to the forked caudal. This family is known only by *Hemirhynchus* from the Eocene of the Paris basin, and *Palæorhynchus* from the Lower Eocene of Glarus.

Family Xiphiidæ.—The Sword-fishes, which are of pelagic habits, and generally attain very large dimensions, are characterised by the production of the upper jaw into a long spear-like rostrum. They are represented at the present day by *Xiphias* (fig. 944), in which pelvic fins are wanting; and *Histiophorus*, in which these organs are long and filiform, and the dorsal fin may be of great length and height. Fossil Sword-fishes from the London Clay have been referred to *Histiophorus* (*Tetrapturus*), although it is not certain that they may not prove generically distinct. The genus *Cælorhynchus*, which was formerly referred to this family, is noticed among the Chimeroidei.

Family Berycidæ.—The *Berycidæ* are characterised by the pres-

ence of mucous-bearing cavities in the head, and by the pelvic fins having (except in *Monocentris*) a single spine, and more than five rays. This family is one of the oldest of the suborder, being abundantly represented in the Chalk. The fossil genera, which may be noticed in alphabetical order, are as follows—viz., *Acrogaster*, from the Upper Cretaceous of Westphalia; *Berycopsis*, from the Creta-

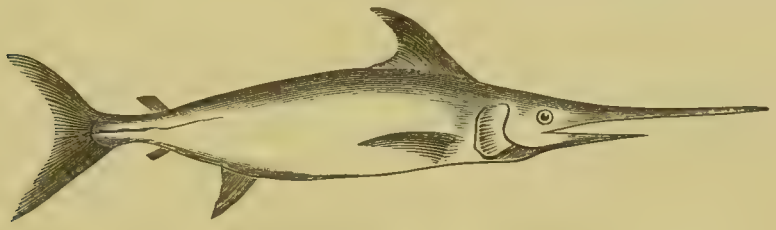


Fig. 944.—*Xiphias*. Greatly reduced.

ceous of England; *Beryx*, in which there is one dorsal fin with several spines, is represented by a single species in the European Chalk, and by two species in the Chalk of the Lebanon, while it is also living at the present day; *Holocentrum*, from the Middle Eocene of Monte Bolca, the Miocene of Malta, and tropical seas of the present day; *Homonotus*, from the Cretaceous of both England and the Lebanon; *Hoplopteryx* (fig. 945), in which the spinous portion of the dorsal fin is greatly developed, and there are also four

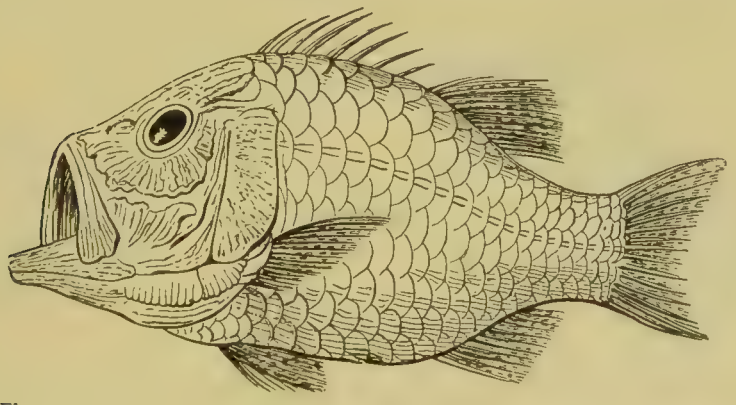


Fig. 945.—*Hoplopteryx lewesiensis*; from the Upper Chalk of Sussex. Reduced. (After Mantell.)

large spines in advance of the anal, is known from the Upper Cretaceous of both Europe and the Lebanon; *Myripristis*, from the Middle Eocene of Monte Bolca, and now found in tropical seas; *Pristigenys*, from Monte Bolca; *Pseudoberyx*, from the Chalk of the Lebanon, characterised by the almost abdominal position of the pelvic fins; *Sphenocephalus*, from the Upper Cretaceous of West-

phalia; and *Stenostoma*, from the English Chalk, of which the affinity is somewhat doubtful.

Perciform Section.—The remaining families of this suborder are characterised by their more or less compressed body; by the dorsal fin, or fins, occupying the greater portion of the back; by the strong development of the spinous part of the dorsal fin, which is at least as long as the soft portion; and by the soft anal corresponding to the soft dorsal. The pelvic fins are thoracic.

Family Scorpænidæ.—This family, which is allied to the following, but has villiform teeth, is known in a fossil state only by a species of the type genus *Scorpæna*, from the Eocene of Algeria.

Family Sparidæ. — The Sea-Breams resemble the Percoids, which we shall notice immediately, in general appearance, but the mouth is either provided in front with chisel-like teeth, or on the sides with molariform ones. All of them inhabit tropical and temperate seas. Among existing genera the sphæroidal palatal teeth of *Chrysophrys* occur in the Red Crag of Suffolk, the Miocene of Malta, and in beds in the Canaries, which are probably referable to the same epoch; while *Sargus* is recorded from the Miocene of France and Würtemberg, the Upper Eocene of Algeria, and the older Tertiary of New Zealand; and *Pagellus* occurs in the Chalk of the Lebanon. It appears, moreover, that many of the crushing palatal teeth of *Chrysophrys* have been described as *Sphærodus*, while the anterior cutting-teeth of the same genus, together with pharyngeal teeth of some of the Carps, have been described as *Capitodus*.

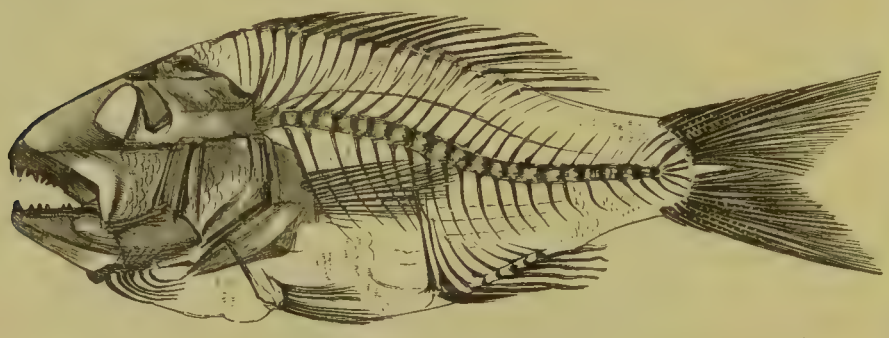


Fig. 946.—Skeleton of *Sparnodus micracanthus*; from the Middle Eocene of Monte Bolca. Reduced

Cutting-teeth of this type, described under the latter name, occur in the Miocene of Austria and Silesia, the Pliocene of Italy, and the Eocene of Northern India. *Sparnodus* (fig. 946) is an extinct genus from the Middle Eocene of Monte Bolca, while the name *Stephanodus* has been applied to a genus from the Upper Chalk of the Sahara, characterised by the breadth and denticulated edges of the cutting-teeth. It may also be observed that teeth from the European

Tertiaries have been described under the names of *Sargodon*, *Soricidens*, and *Asima*.

Family Chætodontidæ. — The Coral-fishes, or Chætodonts, differ from the Percoids in the greater vertical depth of the body, by the continuation of the scales over the median fins, and also by the lateral line stopping short of the caudal fin. Their teeth are bristle-like. These marine tropical fishes (which are generally described under the name of *Squamipennes*) are remarkable for the extreme gorgeousness of their colouring, and are of comparatively small size. They are represented in the Middle Eocene of Monte Bolca by the existing genera *Holacanthus*, *Pomacanthus*, *Ephippus*, *Scatophagus*, and *Toxotes;* the latter being now confined to the Oriental and Australian regions. The earliest Chætodont is *Platycormus*, of the Upper Cretaceous of Westphalia.

Family Percidæ.—With this and the next family of highly specialised Fishes we come to the end of the existing representatives of the present suborder. These Fishes are characterised by the continuous lateral line (fig. 947), the general absence of scales from the median fins, the conical teeth, and the absence of barbels. They are all carnivorous, and inhabit the freshwaters and coasts of

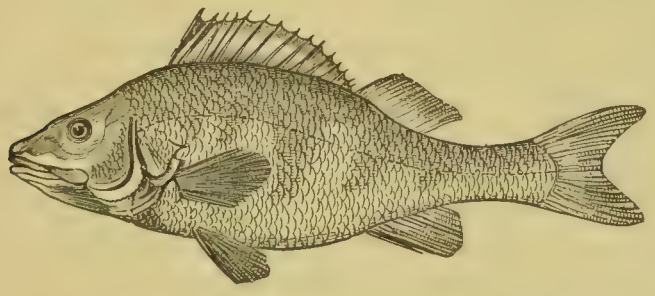


Fig. 947.—The Common Perch (*Perca fluviatilis*). Reduced.

all tropical and temperate regions. The existing genus *Perca* (Perch) occurs in the Upper Miocene of Œningen; while in the Upper Eocene of Aix we have the allied but extinct *Paraperca*. In the Middle Eocene of Monte Bolca, we find species referable to the existing genera *Labrax* (Bass); *Lates*, now inhabiting the Nile and Ganges; *Dules*, of the Indo-Pacific; *Serranus* (Sea-Perch); *Apogon*, of the Mediterranean and Atlantic; and also *Therapon*, of the Indo-Pacific. The extinct *Cyclopoma* and *Smerdis* (fig. 948) likewise occur in the same deposits; the latter being also found at Aix and in the Miocene of Würtemberg. *Acanus* and *Podocys*, from the Lower Eocene of Glarus, are members of this family, which were formerly referred to the *Berycidæ*. In the Eocene of North America we have *Mioplosus*, presenting characters common to

Perca and *Labrax;* and also *Plioparchus*, which does not appear allied to any existing genus.

Family Pristipomatidæ.—This family includes the existing *Pristipoma*, which Dr Günther refers to the *Percidæ*. It occurs fossil in the Eocene of Monte Bolca; and Dr von Zittel would place *Sciænurus*, of the London Clay, in the same family.

Families Aphrodediridæ and Asineopidæ.—These two families are proposed by Professor Cope for the reception of certain North American Eocene Fishes more or less closely allied to the Percoids. The first family includes the genus *Aphrodedirus*, *Erismatopterus*, and *Amphiplaga*, and the second *Asineops*. Professor Cope suggests that *Pygæus*, from the Middle Eocene of Monte Bolca, should perhaps be included in the *Asineopidæ*.

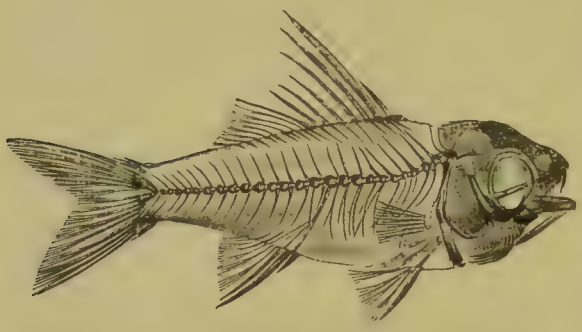


Fig. 948.—Skeleton of *Smerdis minuta;* from the Upper Eocene of Aix, Provence.

Suborder 5. Lophobranchii. — In this small, and to the palæontologist unimportant, suborder the gills are reduced to small round lobes; the gill-cover has only one large plate; and there is a dermal bony skeleton taking the place of the soft integuments. The swim-bladder has no duct.

Family Solenostomatidæ.—The skull is produced into a long rostrum, terminated by the toothless mouth. The gill-openings are wide; there are two dorsal fins; and all the others are well developed. The only existing genus is *Solenostoma*, allied to which is *Solenorhynchus*, of the Italian Eocene.

Family Syngnathidæ.—The Sea-horses and Pipe-fishes differ from the preceding family by the small gill-opening, the single dorsal fin, and the absence of the pelvic fins. The first section, in which the tail is not prehensile, includes the Pipe-fishes, and is represented in the Miocene of Italy and the Middle Eocene of Monte Bolca by the existing genera *Syngnathus* and *Siphonostoma*, and also by the extinct *Calamostoma*, which is allied to *Hippocampus*, but has a caudal fin. The Sea-horses do not appear to be represented in a fossil state.

Suborder 6. Plectognathi.—The last suborder is likewise of small extent, and is characterised as follows. The skin may be naked, or covered with rough scales, scutes, or spines, and the skeleton is imperfectly ossified. There is a small opening leading to the pectinate gills in advance of the pectoral fin; the bones of

the upper jaw are generally welded together; there is a soft dorsal fin; but the pelvic fins are either in the form of spines or absent. There is no duct to the swim-bladder.

Family Balistidæ.—The File-fishes and Coffer-fishes, which are frequently known as *Sclerodermi*, have the jaws somewhat produced, and armed with a small number of teeth; the skin being covered either with rough scales or scutes, and traces of pelvic and spinous dorsal fins always remaining. *Balistes* (File-fish) is characterised by its chisel-like teeth, admirably suited for browsing on the corals on which these fishes subsist. *Protobalistum*, of the Middle Eocene of Monte Bolca, is supposed to be an ancestral type of *Balistes;* while *Protacanthodes*, of the same deposits, is an allied, but distinct form. The Lower Eocene of Glarus has yielded the extinct *Acanthoderma* and *Acanthopleurus*, which are likewise regarded as allied types; while *Glyptocephalus*, of the London Clay, differs from *Balistes* by the regular rows of tubercles with which the body is covered. *Ostracion* (Coffer-fish), in which the body is invested by a carapace of hexagonal scutes articulating by their edges, is now abundant in subtropical and tropical seas, and appears for the first time in the Middle Eocene of Monte Bolca.

Family Diodontidæ.—In the Globe- and Sun-fishes (the *Gymnodontes* of many writers) the body is more or less shortened; the bones of the jaws are united into a trenchant beak, with or without a median suture; and there are no spinous dorsal, or pelvic fins. The dentition is in the form of laminated dental plates. Among the Globe-fishes, in *Tetrodon*, of which no fossil forms have been described, the dental plates are trenchant, and confined to the margins of the jaws. In *Diodon*, however, in addition to these alveolar plates, there is a median crushing-plate (fig. 949), traversed by a suture, developed on the palate of each jaw. The obliquity of the component laminæ of these plates causing an admirable triturating surface. Fossil palatal plates of this genus are found in the Miocene of Malta and Sicily, in the Middle Eocene of Monte Bolca, and also in the Eocene of Algeria and the Arakan coast. The extinct *Enneodon* is an apparently allied genus from the Italian Tertiary. Finally, the huge pelagic Sun-fishes of the genus *Orthagoriscus*, in which the body is compressed and very short, the vertical fins are confluent, and the tail truncate, occur in a fossil state in the Lower Miocene or Upper Eocene of Belgium. The alleged occurrence of this genus in the English Chalk is, however, based on a misinterpretation.



Fig. 949. — Posterior dental plate of *Diodon Scillæ;* from the Miocene of Malta.

At the conclusion of this order we may mention the genus

Ancistrodon, founded upon detached teeth from the Chalk of France; similar teeth also occurring in the Cretaceous of Texas. These teeth are generally regarded as pharyngeal teeth of Teleostei, although it has been suggested that they may prove to be anterior teeth of Pycnodont Ganoids.

LITERATURE OF PISCES.

1. AGASSIZ (L.)—"Recherches sur les Poissons Fossiles." Neuchâtel. 1833-44.
2. —— "Monographie des Poissons fossiles du Vieux Grès Rouge." Neuchâtel. 1844.
3. COPE (E. D.)—"The Vertebrata of the Cretaceous Formations of the West." 'Rep. U.S. Geol. Survey of the Territories,' vol. ii. (1875).
4. DAVIS (J. W.)—"On the Fossil Fishes of the Carboniferous Limestone Series of Great Britain." 'Trans. Roy. Dublin Soc.' (2), vol. i. (1887).
5. —— "The Fossil Fishes of the Chalk of Mount Lebanon in Syria." *Ibid.*, vol. iii. (1887).
6. EGERTON (P. DE M.)—"The Nomenclature of the Fossil Chimæroid Fishes." 'Quart. Journ. Geol. Soc.' vol. iii. (1847).
7. GÜNTHER (A.)—"Description of Ceratodus." 'Phil. Trans.' 1871.
8. —— "An Introduction to the Study of Fishes." Edinburgh. 1880.
9. HANCOCK (A.) AND ATTHEY (J.)—"On Dipterus and Ctenodus." 'Ann. and Mag. Nat. Hist.,' ser. 4, vol. vii. (1871).
10. HASSE (C.)—"Das Naturliche System des Elasmobranchier auf. Grundlage des Baues und der Entwickelung ihrer Wirbelsauler." Jena. 1879.
11. HUXLEY (T. H.)—"Essay upon the Systematic Arrangement of the Fishes of the Devonian Epoch." 'Mem. Geol. Survey of Great Britain.' Decade X. (1861).
12. —— "Structure of Crossopterygian Ganoids." *Ibid.* Decade XII. (1866).
13. —— "Structure of Ceratodus." 'Proc. Zool. Soc.' 1876.
14. KOKEN (E.)—"Ueber *Pleuracanthus*." 'Sitz. Ges. Nat. Berlin. 1889. No. 3.
15. MIALL (C. J.)—"On the Genus *Ceratodus*, with Special Reference to the Fossil Teeth found at Maledi, Central India." 'Palæontologia Indica' (Mem. Geol. Surv. Ind.), ser. 4. vol. i. (1878).
16. —— "Sirenoid and Crossopterygian Ganoids." 'Palæontographical Society.' 1878.
17. NEWBERRY (J.)—"Palæontology of Ohio" (Carboniferous and Devonian Fishes). 1873 and 1875.
18. NEWTON (E. T.)—"The Chimæroid Fishes of the British Cretaceous Rocks." 'Mem. Geol. Survey of Great Britain.' Monograph IV. (1878).
19. OWEN (R.)—"Odontography." London. 1840-45.
20. PANDER (C. H.)—"Die Placodermen." 1857.
21. —— "Die Ctenodipterinen des Devonischen Systems." 1858.
22. —— "Die Saurodipterinen, Dendrodonten, Glyptolepiden, und Cheirolepiden des Devonischen Systems." 1860.

23. PANDER (C. H.)—"Fossilen Fische des Silurischen Systems." 1856.
24. POWRIE (J.) AND LANKESTER (E. R.)—"Monograph of the Fishes of the Old Red Sandstone of Britain (*Cephalaspidæ*)." 'Palæontographical Society.' 1868-70.
25. TRAQUAIR (R. H.)—"Description of *Pygopterus Greenockii*," &c. 'Trans. Roy. Soc. Edinb.,' vol. xxiv. (1867).
26. —— "Monograph of the Ganoid Fishes of the British Carboniferous Formations (*Palæoniscidæ*)." 'Palæontographical Society.' 1877.
27. —— "On the Genus *Dipterus*," &c. 'Ann. and Mag. Nat. Hist.,' ser. 5, vol. ii. (1878).
28. —— "On the Structure and Affinities of *Tristichopterus alatus*." 'Trans. Roy. Soc. Edinb.,' vol. xxvii. (1875).
29. —— "On the Cranial Osteology of *Rhizodopsis*." *Ibid.*, vol. xxx. (1881).
30. —— "Report on Fossil Fishes collected in Eskdale and Liddesdale." Pt. 1. Ganoidei. *Ibid.*, vol. xxx. (1881).
31. —— "Structure and Systematic Position of *Cheirolepis*." Also "On Some Fossil Fishes from the Neighbourhood of Edinburgh." 'Ann. and Mag. Nat. Hist.,' ser. 4, vol. xv. (1875).
32. —— "On the Structure and Affinities of the *Platysomidæ*." *Ibid.*, vol. xxix. (1879).
33. —— "On the Nomenclature of the Fishes of the Old Red Sandstone of Great Britain." 'Geol. Mag.,' decad. 3, vol. v. (1888).
34. —— "On the Structure and Classification of the *Asterolepidæ*." 'Ann. Mag. Nat. Hist.,' ser. 6, vol. ii. (1888).
35. —— "*Homosteus* compared with *Coccosteus*." 'Geol. Mag.,' decad. 3, vol. vi. (1889).
36. WHITEAVES (J. F.)—"Illustrations of the Fossil Fishes of the Devonian Rocks of Canada." Pts. I. and II. 'Trans. Roy. Soc. Canada,' vols. iv. and vi. (1887 and 1889).
37. WOODWARD (A. S.)—"On some New Species of *Holocentrum*, from the Miocene of Malta, with a List of Fossil *Berycidæ*." 'Geol. Mag.,' decad. 3, vol. iv. (1887).
38. —— "On Some Remains of the Extinct Selachian *Asteracanthus*, from the Oxford Clay of Peterborough." 'Ann. Mag. Nat. Hist.,' ser. 6. vol. ii. (1888).
39. —— "On the Fossil Fish-spines named *Cœlorhynchus*." *Ibid.*
40. —— "On the genus *Rhacolepis*." 'Proc. Zool. Soc.' 1887.
41. —— "On the genus *Notidanus*." 'Geol. Mag.,' decad. 3, vol. iii. (1886).
42. —— "Synopsis of the Vertebrate Fossils of the English Chalk." 'Proc. Geol. Assoc.,' vol. x. (1887).
43. —— "Catalogue of Fossil Fishes in the British Museum." Pt. I. Elasmobranchei. 8vo, London (1889).
44. —— "On the Occurrence of *Onychodus* in the Lower Old Red of Herefordshire." 'Geol. Mag.,' decad. 3, vol. v. (1888).
45. —— "On the Palæontology of Sturgeons." 'Proc. Geol. Assoc.,' vol. xi. (1889).
46. ZITTEL (K. A.)—"Handbuch der Palæontologie." Abth. I., vol. iii., pts. 1, 2. 8vo, Munich (1887-88). Critically reviewed by A. Smith-Woodward in the 'Geol. Mag.' for 1889.

CHAPTER LI.

CLASS AMPHIBIA.

GENERAL STRUCTURE AND ORDERS.

The Amphibia, which comprise the Frogs and Toads, Salamandroids, Cæcilians, and the extinct Labyrinthodonts, and are sometimes known as the Batrachia, agree in so many points of structure with the more generalised Fishes, that Professor Huxley groups the two classes together under the common name of Ichthyopsida. Recent observations on fossil forms, tend, however, to show in the other direction a transition from the Amphibia to the more generalised Reptilia. The Amphibia as a whole differ from Fishes mainly by the circumstance that when median fins are present they are devoid of fin-rays; and that the limbs, when present, contain the same skeletal elements as those of the higher classes. They agree with Fishes in having branchiæ in their earlier stages of life, but these very frequently disappear in the adult, when respiration is carried on entirely by means of the lungs. An epidermal exoskeleton is generally wanting. There is no amnion, and at best but an imperfect allantois in the embryo. In existing forms the cranium always articulates to the vertebral column by two distinct exoccipital condyles, but in a few Labyrinthodonts these were not ossified. The mandible articulates to the cranium without the intervention of a suspensorium; so that the skull, like that of the Dipnoid Fishes, is autostylic. A large parasphenoid is always present; and cranial bones are largely developed, although their number is generally less than in Fishes. The external nares are terminal in nearly all cases. The vertebral column is more or less completely ossified, and can generally be differentiated into cervical, dorso-lumbar, sacral, and caudal regions; the sacrum but rarely comprising more than a single vertebra. The infraneural segments of the vertebral column are frequently amphicœlous, and in recent forms each bears its own arch; but in certain Labyrinthodonts, as we shall see below, the neural arches are carried by alter-

nate vertebral segments, and from circumstances to be detailed in the sequel it is inferred by Professor Cope and others that the vertebral bodies of existing Amphibians are really intercentra, carrying the neural arches which have been shifted to them from the lost centra. The ribs may articulate to the vertebra by a single (upper) transverse process; but in Salamandroids and Labyrinthodonts the vertebræ also carry an inferior rib-facet, when the heads of the ribs are consequently double. As a rule no ribless (lumbar) vertebræ occur, and sternal ribs are wanting. The sternum, which is never present in Fishes, appears in the Amphibia in the middle line of the chest, and may be extended anteriorly as an omo- and episternum (fig. 974, B). The pectoral and pelvic girdles are well developed; the former (*ibid.*) in recent forms having, however, no clavicle or interclavicle, although it is nearly certain that these bones are represented in the thoracic buckler of the Labyrinthodonts. A distinct rod-like precoracoid (fig. 974, B) occurs in recent forms. In the pelvis the pubis is frequently unossified, and if ossified is much smaller than the ischium. In most cases the ischium and the cartilaginous or bony pubis of either side unite to form a continuous plate, in which the obturator foramen is not represented, although there is a small perforation; and the ischia meet in a ventral symphysis. The body of the ilium may be almost wholly in advance of the acetabulum. The limbs vary greatly in their proportionate length in the different orders, and may be entirely absent; while the carpals and tarsals may be unossified. The limb bones of the Labyrinthodonts approximate to those of the Anomodont Reptiles. The carpus and tarsus always have a centrale, and in some of the primitive Labyrinthodonts there may be at least three centralia in the latter. The fourth and fifth tarsalia always remain distinct from each other in those forms which have five digits. The latter number is found in the Labyrinthodonts, but in some existing forms the digits may be reduced to three or two. The number of the phalangeals in the digits of pentedactylate forms, counting from the first to the fifth, does not exceed 2, 2, 3, 3, 3, and this number may be reduced in some existing forms. As a rule the tail is comparatively short.

Teeth are usually present on the premaxilla, maxilla, vomer, and the dentary bone of the mandible; but are generally wanting on the palatine and pterygoid, although present on the latter, and also on the parasphenoid, in many Labyrinthodonts. These teeth are usually anchylosed to the bone, and in existing forms are of simple structure. In the Labyrinthodonts the structure of the teeth may, however, become very complex by foldings of the dentine, this structure being an extreme development of that met with in certain Ganoids; and in some of these forms the usually large pulp-cavity

may be greatly reduced. In existing forms there is generally no exoskeleton, and if scutes or scales are developed they are buried in the skin; but in the Labyrinthodonts bony scutes were very generally present, although frequently restricted to the ventral aspect of the body.

A marked, although not universal, feature in the class is the change from a respiration by gills to one by lungs; this change being accompanied by other structural alterations, and termed a metamorphosis. In some instances only external gills are developed, which form a plume on either side of the neck; and it is these gills which persist in such forms as do not undergo a metamorphosis. In those groups, however, in which a metamorphosis takes place internal gills may be developed for a short period.

That the Amphibia have taken their origin from primitive Fishes allied to the Dipnoi and Ganoidei is pretty evident. Evidence of

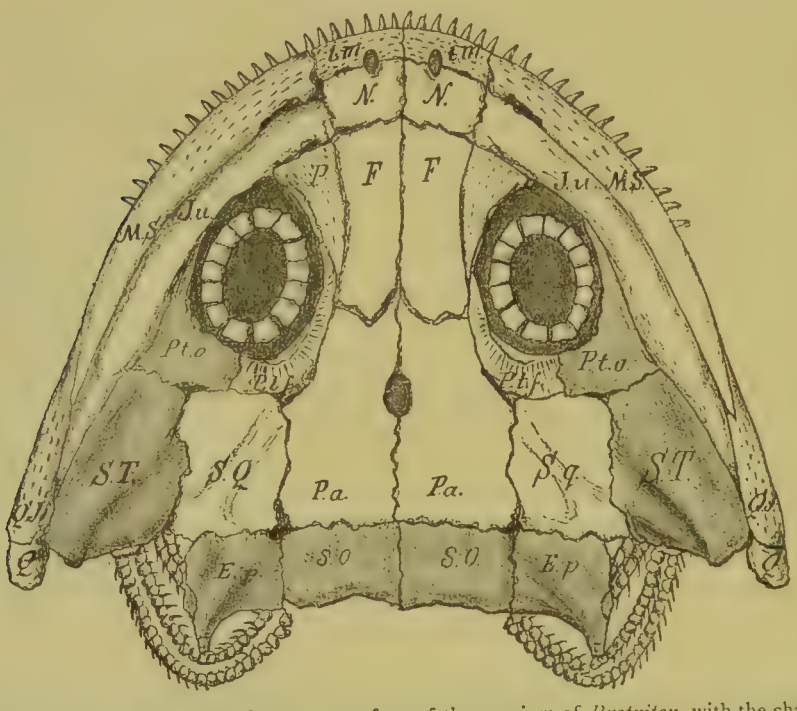


Fig. 950.—Enlarged view of the upper surface of the cranium of *Protriton*, with the characteristic Labyrinthodont bones shaded; from the Permian of Bohemia. *N*, Nasal; *F*, Frontal; *P.a*, Parietal; *S.O*, Supraoccipital; *E.p*, Epiotic; *S.T.*, Supratemporal; *S.q*, Squamosal; *P.t.f*, Postfrontal; *Ju*, Jugal; *P.t.o*, Postorbital; *im*, Premaxilla; *M.S*, Maxilla; *QJ*, Quadratojugal; *Q*, Quadrate. (After Fritsch.)

affinity with the primitive Ganoids is indeed very clearly shown by the so-called labyrinthic structure of the teeth of nearly all the Palæozoic Amphibia, since we find a similar type of dental structure obtaining in many of the early Ganoids, and nowhere else in the

whole animal kingdom. The similarity in the structure of the vertebral column of the earlier Elasmobranch and Ganoid Fishes with that of the Labyrinthodont Amphibians is also important evidence pointing in the same direction.

This class may be divided into the four orders, Labyrinthodontia, Apoda, Ecaudata, and Caudata. The first is totally extinct, the second is at present unknown before the existing epoch, while we have no certain record of the occurrence of the third before the Cretaceous, and of the fourth previously to the Tertiary.

Order I. Labyrinthodontia.—Since the name of this order is not strictly applicable to all its members it has been proposed to substitute the term Stegocephala; but, as the same objection might be taken to a large number of terms in use, such a change seems unnecessary. Using, then, the Labyrinthodontia as including the Ganocephala and Microsauria of some writers, its members may be characterised by the following features. The body is more or less elongated, and furnished with a tail; the skull has paired supraoccipitals (fig. 950, *S.O*), and its postero-lateral regions are roofed over by a postorbital (*P.t.o*) anteriorly, and a supratemporal (*S.T*) posteriorly. There is, moreover, very generally an epiotic [1] (*E.p*); the orbits frequently have a bony ring in the sclerotic; and there is a



Fig. 951.—Ventral aspect of the thoracic buckler of *Actinodon Frossardi*; from the Permian of France; two-fifths natural size. *ent*, Interclavicle; *ep*, Clavicle; *s.cl*, Supraclavicle; *o*, Scapula. (After Gaudry.)

parietal foramen. Palatine and vomerine teeth are very generally present, and the dentine of the teeth is frequently more or less folded, or plicated, from the sides. The centra of the vertebræ, which are amphicœlous, may be imperfectly ossified, and frequently retain a notochordal canal in the middle. Usually there is a buckler on the inferior surface of the thorax, consisting of one median, and two lateral flattened bones, probably representing the interclavicle and clavicles; the relations of these bones being shown in fig. 951.

[1] Dr Baur regards this bone as the opisthotic; and also considers that the bone here termed the squamosal is the supratemporal, and *vice versâ*.

Posteriorly to this thoracic buckler an armour of dermal scutes is generally developed on the ventral surface of the body; and in some cases this armour may cover the entire body, the form of the scutes, or scales, then varying considerably in the different regions. Four paired pentedactylate limbs were usually present.

The pterygoids are always separated from one another in the median line. The pelvis [1] of the more typical forms is remarkably like that of the Pariasaurian Anomodont Reptiles, presenting the same absence of an obturator foramen.

The paired supraoccipital ossifications constitute a feature found elsewhere only among the Ganoid Fishes; and the frequent ossification of the articular bone of the mandible is also a character not found elsewhere in the class. In many cases the external surface of the bones of the skull (fig. 952), and of the thoracic buckler, is

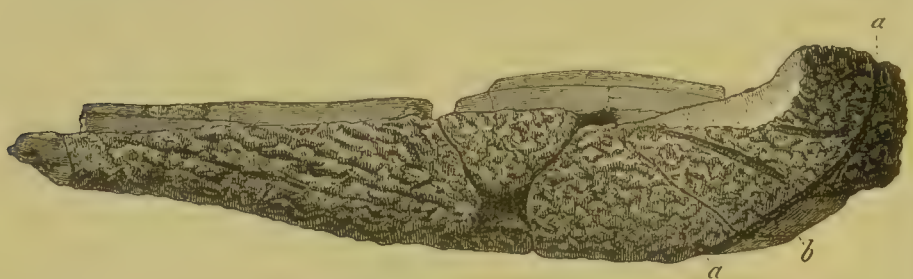


Fig. 952.—Lateral view of the imperfect left ramus of the mandible of *Pachygonia incurvata*; from the Lower Mesozoic of India. The letters indicate mucous canals. (After Huxley.)

sculptured by a series of irregular grooves and ridges; traversed in the former instance by a number of mucous canals. From the occurrence of a similar sculpture in the Pariasaurian Anomodonts and the Crocodilians, Professor Seeley regards these groups as directly descended from Labyrinthodonts; and it is evident that the passage from the Labyrinthodonts to the former group of Reptiles is almost a complete one. The gills (fig. 953) of the young are generally lost in the adult; but in one group the external gills persist.

Labyrinthodonts range in Europe generally from the Carboniferous to the Trias, and are especially abundant in the Permian; but one genus (*Rhinosaurus*) persisted to the Lower Jurassic. In North America and India this order is abundantly represented in strata mainly representing the period from the Carboniferous to the Trias. According to the views of Professor Cope and Dr Fritsch, this order is to be regarded as one presenting generalised characters, some of which approximate to those of modern Amphibia, while others are

[1] It should be observed that in the figure of the pelvis of *Eryops* given in Zittel's 'Palæontologie,' abth. i., vol. iii., pt. ii., p. 364, fig. 351, the hinder end of the ischium is mistaken for the pubis.

Reptilian; and we may probably regard the Anomodont Reptiles as having taken their origin from a group closely allied to the Labyrinthodonts, if not actually from this order. As regards the subdivisions of the order there is still considerable uncertainty, and all such divisions must consequently be regarded as more or less provisional. Dr Fritsch has, indeed, proposed to range the families under four series or suborders, according to the external contour of the body and the nature of the vertebral column; this grouping being provisionally adopted in the present work, with some emendation of nomenclature.

Suborder 1. Branchiosauria.—In this suborder the external appearance approaches that of the modern Salamanders. The vertebræ have centra composed of a single piece, which retains traces of the notochord; the ribs are short and straight; and the neural canal is dilated in the middle of each vertebra. The teeth are simple in structure, and internal gills were developed in the young. Some authorities include the next two groups in the present suborder under the name of Lepospondyli.

Family Protritonidæ.—The *Branchiosauridæ* of Dr Fritsch, being founded on a name which is apparently a synonym, may be better known as the *Protritonidæ*. They are characterised by the great breadth of the skull (fig. 950), and the smooth teeth. Typically the palatines, according to Dr Credner, are small transversely elongated bones lying in the anterior part of the skull, and not joining the maxillæ; this arrangement being similar to that found in the Ecaudata. The type genus *Protriton* (*Branchiosaurus* or *Pleuronura*) is found abundantly in the Permian of the Continent; and its development has been fully worked out by Dr Credner from the study of a large number of specimens of all ages. The specimen shown in fig. 953 exhibits the nearly entire skeleton of a small individual, while the details of the cranial structure are exemplified in the greatly enlarged skull shown in fig. 950.



Fig. 953.—Ventral aspect of the nearly entire skeleton of a young individual of *Protriton petrolei*; from the Permian of France. (After Gaudry.)

According to the observations of Dr H. Credner, it appears that the youngest specimens known were 25 mm. in length, in which stage the creature was aquatic, and breathed by gills, which were supported by four pairs of arches. By the time they attained a length of from 60

to 70 mm., these larvæ cast their gills, and became air-breathers; their development being thus analogous to that of the existing Salamanders. The adults measure from 100 to 160 mm. In the course of the metamorphosis the skull decreases somewhat in width, and the thoracic buckler grows much more rapidly than the scapula and coracoid, while, curiously enough, the pelvis shifts its position, and thus increases the number of presacral vertebræ from 20 to 26. In the larva the underside of the body is naked (fig. 953), but in the adult there is a complete armour of bony scutes on this aspect.

Other genera of which some may perhaps be included in this family are *Amphibamus*, from the Carboniferous of Illinois; *Pelion*, from that of Ohio; *Batrachiderpeton*, from the Carboniferous of Britain; *Hylerpeton*, from that of Nova Scotia; *Dawsonia*, from the Permian of Bohemia; and *Sparodus*, from the latter deposits. *Batrachiderpeton* is remarkable for the absence of maxillary teeth, and the clustering of the palato-vomerine teeth; *Sparodus* presenting the latter feature, but retaining the maxillary teeth. The palatines of the latter genus are splint-like bones interposed between the vomers and maxillæ.

Family Apateonidæ.—In this family the skull (fig. 954) is triangular and comparatively narrow, while the teeth are marked by small grooves at their summits. The type genus *Apateon* is found in the Carboniferous rocks of Germany, while the allied *Melanerpeton* is from the Permian of Bohemia. An enlarged view of the dorsal aspect of the skull of the latter genus is shown in fig. 954, the retention of the internal gills indicating that it belonged to an immature individual.

Suborder 2. Aïstopoda.—In this remarkable group the body has a snake-like form, with well-developed ribs, but probably without either pectoral or pelvic girdles or limbs. The teeth are not folded; and Dr Fritsch considers that the external gills persisted throughout life.

Family Dolichosomatidæ.—This family, which is equivalent to both the *Plegothonidæ* and *Molgophidæ* of Professor Cope, is represented in the Carboniferous of Britain and the Permian of Bohemia by *Dolichosoma* and *Ophiderpeton*. In the former the skull is long and narrow, with no sculpture on the bones, and it is probable that the body was entirely naked; but in the latter the skull may have been shorter, and there was an armour on both surfaces of the body, the scutes on the ventral side being long oat-like splints, while those on the back were rounded and shagreen-like. The ossified gill-supports were furnished with small enamel-like denticules. One of the species of *Dolichosoma* attained a length of about two feet. *Plegethontia* and *Molgophis*, from the Carboniferous of Ohio, appear to be nearly related. *Palæosiren*, from the Permian of Bohemia, is a gigantic form provisionally included in this family,

of which the length is estimated at forty-five feet; while *Adenoderma* of the same deposits may indicate a distinct family.

From the many resemblances presented by the *Dolichosomatidæ* to the existing Apoda, Dr Fritsch considers it probable that they must be regarded as nearly related to the ancestral forms from which that group has been derived.

Suborder 3. Microsauria.—The Labyrinthodonts included in this suborder resemble Lizards in outward appearance, and have the centra of the vertebræ more or less elongated, and long, curved ribs.

Family Urocordylidæ.—This family—the *Nectridea* of Professor Miall and the *Ptyoniidæ* of Professor Cope—comprises stout, long-

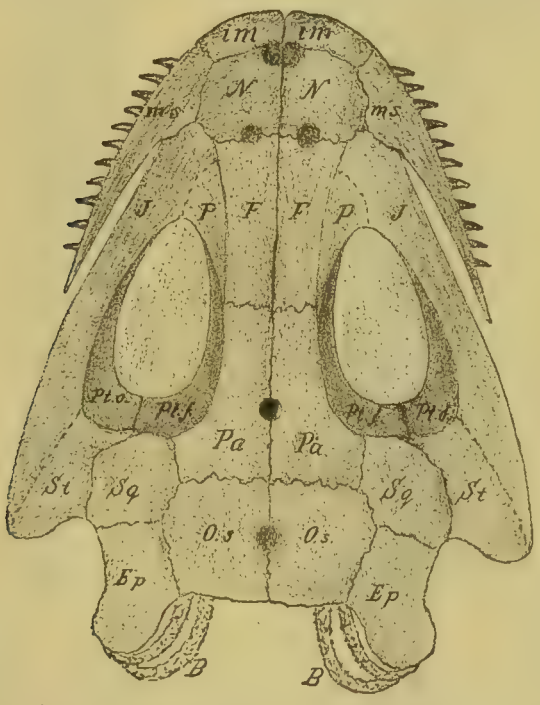


Fig. 954.—Upper surface of the skull of *Melanerpeton pusillum*; from the Permian of Bohemia; six times natural size. *B*, Branchiæ; *O.s.*, supra-occipital; other letters as in fig. 950. (After Fritsch.)

tailed forms, in which the epiotic cornua of the skull are much produced; the cranial bones are pitted; the neural spines and chevrons of the caudal vertebræ are much dilated at their extremities and pectinated; and caudal ribs are wanting. The type genus *Urocordylus*, as well as *Ceraterpeton*, occurs in the Carboniferous of Britain and Ohio, and also in the Permian of Bohemia; one species of the former attaining a length of about twenty inches. *Lepterpeton* is characteristic of the Carboniferous of Britain and Ohio; other

genera from the latter deposits being *Ptyonius*, *Œstocephalus*, *Hyphasma*, and probably *Sauropleura*.

Family Limnerpetidæ.—In the one genus *Limnerpeton*, of the Permian of Bohemia, the naked body is more elongated and the tail shorter than in the preceding family; the skull being broad and

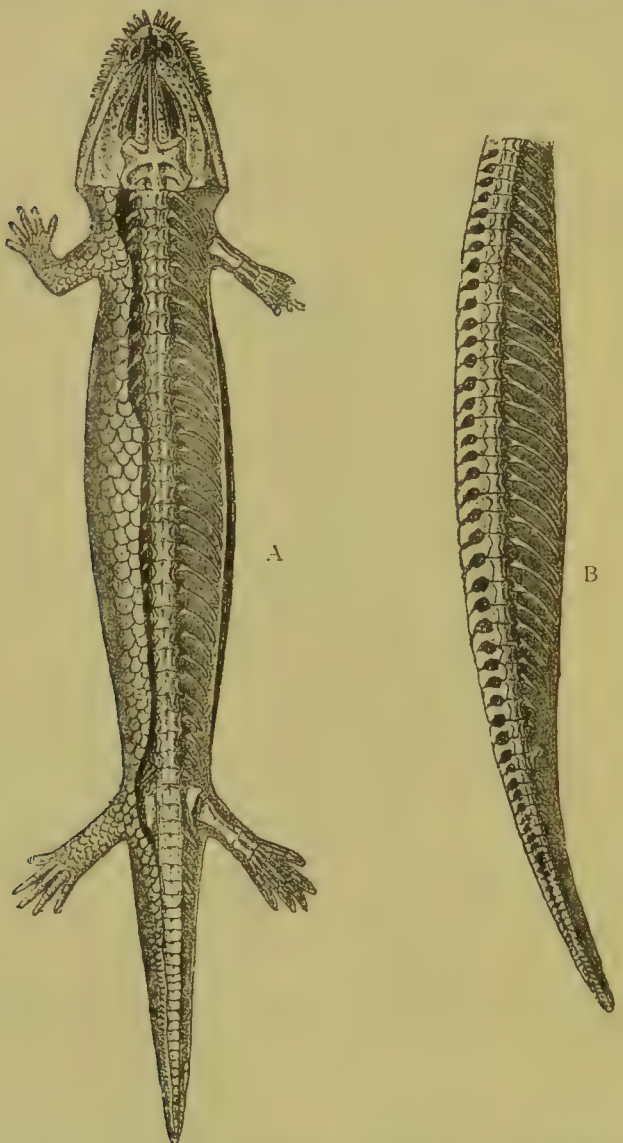


Fig. 955.– *Sceleya pusilla*; from the Permian of Bohemia. A, Under surface with scutes removed on the left side; and B, Right lateral view of the skeleton of the caudal region. Enlarged. (After Fritsch.)

Frog-like, with smooth bones; and the upper and lower processes of the caudal vertebræ simple. The teeth are small, with their summits either smooth or folded.

Family Hyloplesionidæ.—This family is readily recognised by the somewhat narrow head, the smooth cranial bones, and the envelopment of the whole body (fig. 955, A) in an armour of scutes. The caudal ribs (fig. 955) are well developed. It comprises the genera *Hyloplesion*, *Seeleya* (fig. 955), *Ricnodon*, and *Orthocosta*, from the Permian of Bohemia. *Hylonomus* and *Smilerpeton*, from the Carboniferous of Nova Scotia, are imperfectly known forms which may belong to the same family, in which case the name *Hylonomidæ* might be adopted. All the species are of small size.

Family Microbrachidæ.—This family includes small slender forms, with short pectoral limbs, strongly sculptured cranial bones, and scutes covering the entire body. The type genus *Microbrachis* occurs in the Permian of Bohemia, and has a long narrow skull. Three species are known. Another representative of this family is *Tuditanus*, of the Carboniferous of Ohio, characterised by its broad and expanded skull. *Cocytinus*, of the same deposits, may be provisionally placed in this family.

Suborder 4. Labyrinthodontia Vera.—The genera included in this group are characterised by their Crocodile-like bodies; the disk-like centra of the vertebræ, when these are fully ossified; by the vertebral column being, at least in the young, very generally of the types known as *rhachitomous* and *embolomerous;* by the teeth being more or less folded; and by the outer surface of the skull bearing a more or less strongly-marked sculpture, frequently accompanied by the presence of the so-called mucous canals. Some authorities divide this group into the *Temnospondyli* and *Stereospondyli*, according to the incomplete or complete ossification of the vertebral centra; but Dr Fritsch regards the whole series as constituting a single group—a view which is supported by the circumstance that in many of those forms in which the vertebræ are fully ossified in the adult, in the young stage their ossification is incomplete.

Before proceeding further it will be advisable to briefly consider the nature of the above-mentioned types of vertebral structure. In certain genera like *Diplospondylus*[1] (*Diplovertebron*) and *Cricotus* each caudal vertebra consists of an anterior centrum carrying the neural arch, and a posterior intercentrum to which the chevrons are united. These intercentra, according to the views of Professor Cope, correspond with the chevron-bearing intercentra of *Clepsydrops* among the Anomodont Reptilia, and the wedge-bones of *Sphenodon* among the Rhynchocephalians; this type of structure being known as the *embolomerous*. In the trunk vertebræ of other genera like *Trimerorhachis* (fig. 957) and *Archegosaurus* each vertebra (fig.

[1] This name has been proposed in lieu of the hybrid *Diplovertebron*.

956) consists of four portions—viz., a basal intercentrum (hypocentrum), a pair of pleurocentra, and a neural arch. In this *rhachitomous* type Professor Cope regards the pleurocentra as representing the centrum of the embolomerous type, since they both carry the arch; and as he finds that the functional centra in other forms, like *Chelydosaurus*, apparently correspond to the intercentra of *Archegosaurus*, while the pleurocentra are small and apparently about to disappear, it is argued that in other Amphibia the real centra are totally wanting, and the vertebral bodies, which in the caudal region have the chevrons united to them, are really intercentra, to which the neural arches have been shifted. Professor Cope regards the rhachitomous and embolomerous structures as characters of at least family value; but Dr Fritsch considers that the two types occur in different regions of one and the same species, as we

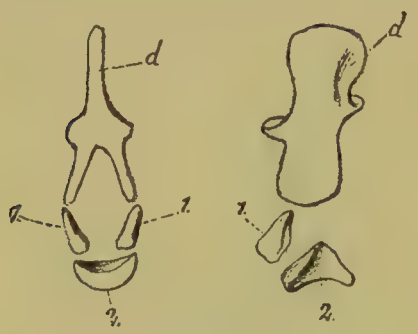


Fig. 956.—Diagram of a rhachitomous vertebra; from the front and left side. 1, Pleurocentra; 2, Intercentrum; *d*, Neural spine. (After Fritsch.)

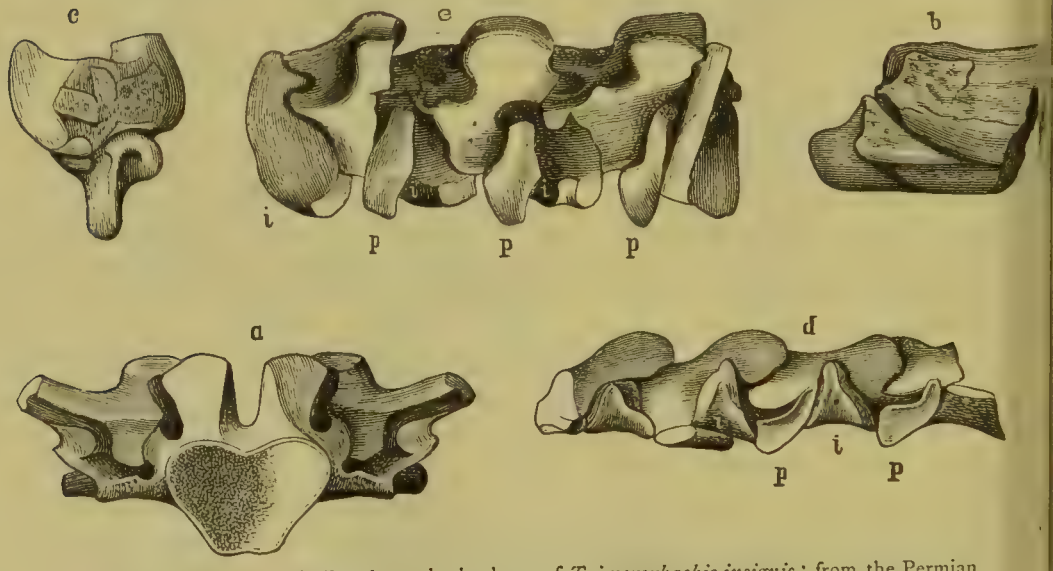


Fig. 957.—Parts of skull and vertebral column of *Trimerorhachis insignis*; from the Permian of North America. *a*, Basi- and exoccipitals; *b*, *c*, Lateral and posterior view of angle of mandible; *d*, *e*, Portions of vertebral column depressed by pressure; *i*, Intercentra; *p*, Pleurocentra. (After Cope.)

know to be the case in some of the Ganoid Fishes (*supra*, p. 959), where we find in *Eurycormus* and *Aspidorhynchus* a rhachitomous type of vertebræ in the cervical and dorsal regions, and an embol-

omerous type in the caudal. An excellent example of the rhachitomous type of vertebra is shown in fig. 960, the pleurocentra being omitted.

It should be observed that this interpretation of the homology of the rhachitomous vertebra is not accepted by Mr Hulke.

Family Archegosauridæ. — The well-known genus *Archegosaurus*, ranging in Europe from the Carboniferous to the Permian, may be taken as the type of a family, which for the present may include most of those forms in which the dorsal vertebræ are of the

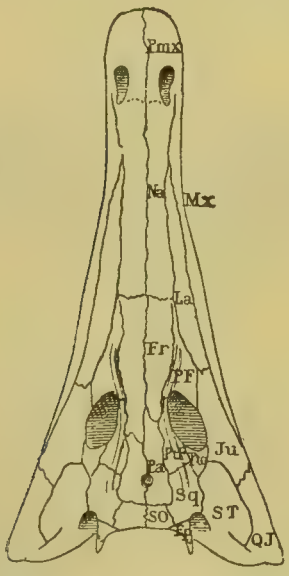


Fig. 958.—Upper surface of the cranium of *Archegosaurus*; from the Carboniferous. Reduced. *Pmx*, Premaxilla; *Mx*, Maxilla; *Na*, Nasal; *La*, Lachrymal; *Fr*, Frontal; *PF*, Prefrontal; *Pa*, Parietal; *PtF*, Postfrontal; *PtO*, Postorbital; *Ju*, Jugal; *QJ*, Quadratojugal; *Sq*, Squamosal; *ST*, Supratemporal; *Ep*, Epiotic; *SO*, Supraoccipital. (After Miall.)

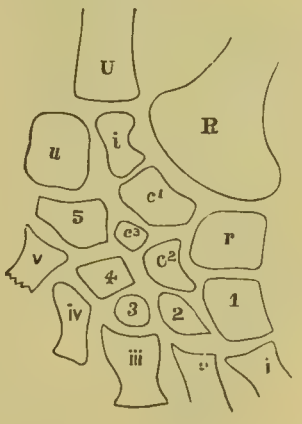


Fig. 959.—Upper aspect of the right carpus of *Eryops*; from the Permian of North America. Reduced. *R*, Radius; *U*, Ulna; *r*, Radiale; *i*, Intermedium; *u*, Ulnare; c^1, c^2, c^3, Centralia; 1-5, Carpalia; i.-v., Metacarpals. (After Baur.)

rhachitomous type throughout life. Its members have, indeed, been split up into the *Melosauridæ*, *Trimerorhachidæ*, and *Eryopidæ*; but the observations of Dr Fritsch indicate that for the present at least such divisions are not definable. According to the last-named authority this family may be characterised as including Labyrinthodonts of medium dimensions; having cylindrical teeth of varying size, in which the folding of the dentine is comparatively slight; the upper surface of the skull being pitted; the supraoccipitals ridged; and the trunk vertebræ rhachitomous, and the caudal usually embolomerous. A ring of bones is usually developed in the sclerotic; the ventral surface of the body is always covered with

scutes; and the palatines form long splints lying on the inner side of the maxillæ. This family is evidently the most primitive one of the entire order; the vertebral column displaying an arrest of development at a stage which is transitional in higher forms. It is further remarkable for the small size of the coracoid, in which respect this group agrees with the Salamanders and some of the Anomodont Reptiles. The humerus has distinct condyles, as in the latter group; and in the pelvis the pubis is ossified, and, like that of some Anomodonts, unites with the ischium without the intervention of an obturator foramen. The tarsus and carpus (fig. 959) are

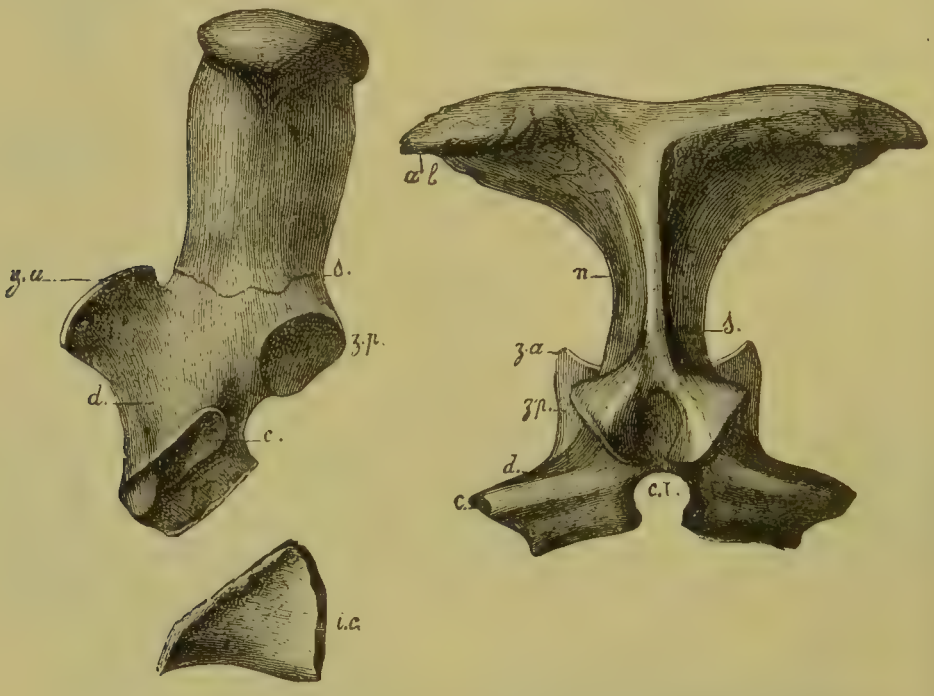


Fig. 960.—Left lateral aspect of the arch and intercentrum, and posterior aspect of the arch, of a dorsal vertebra of *Euchirosaurus Rochei*; from the Lower Permian of France. *n*, Neural spine, with lateral expansions, *al*; *s*, Suture between spine and arch; *z.a*, Pre-, *z.p*, Postzygapophysis; *d*, Transverse process; *c*, Rib-facet; *c.r*, Neural canal; *i.c*, Intercentrum. (Adapted from Gaudry.)

characterised by the number of centralia, there being, according to the interpretation here followed, four of these bones in the former and three in the latter; and the first centrale articulating respectively with the tibia in the tarsus and with the radius in the carpus. This type of tarsal and carpal structure is evidently the most primitive yet observed.

In *Archegosaurus*, and also in *Zygosaurus* of the European Permian, and *Trimerorhachis* of the reputed equivalent strata of North America, the occipital condyles were not ossified; but they were

bony in many of the other genera. The following genera from the Permian of Europe have vertebræ agreeing in structure with those of the typical forms, and may be provisionally placed in the same family; they are named *Melosaurus*, *Osteophorus*, *Zygosaurus*, *Chelydosaurus*, *Cochleosaurus*, *Gaudrya*, *Actinodon*, and *Euchirosaurus*. *Sphenosaurus*, from the Permian of Bohemia, has also been placed here, although some writers regard it as a Reptile. The name *Discosaurus* has also been applied to a member of this group from the

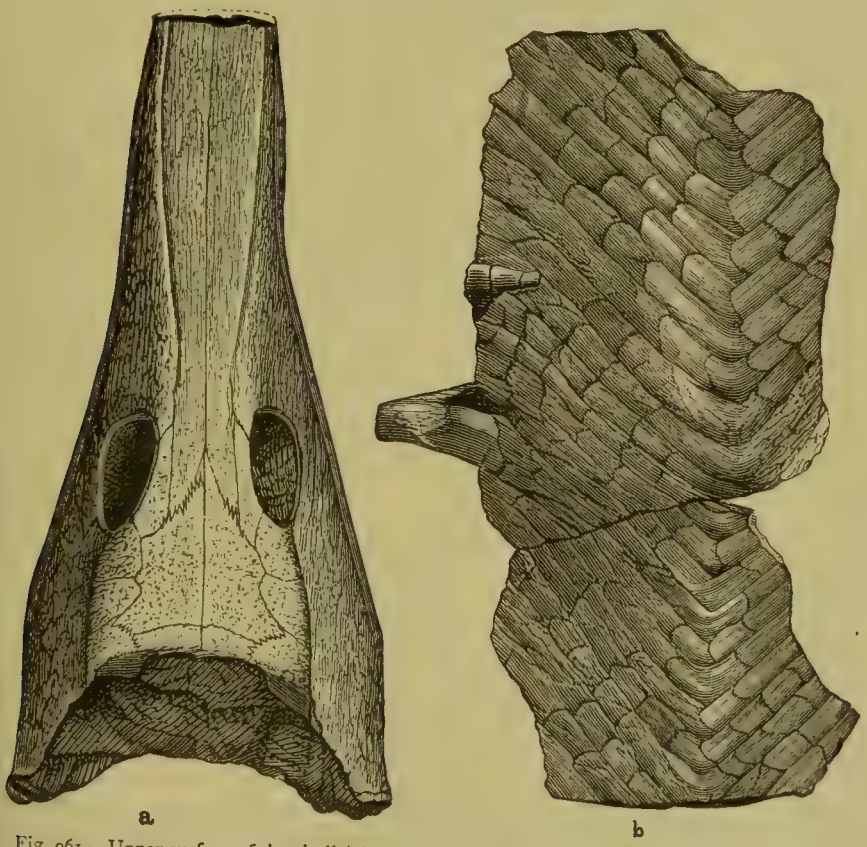


Fig. 961.—Upper surface of the skull (*a*), and ventral scutes (*b*) of *Cricotus heteroclitus*; from the Permian of North America. One-half natural size. (After Cope.)

Permian of Dresden, but it is preoccupied in the Sauropterygia. Portions of a vertebra of *Euchirosaurus*, from Autun in France, are shown in fig. 960, the neural spine being remarkable for the great lateral expansion of its summit; according to Dr Fritsch's restoration (fig. 956) the pleurocentra belonging to this vertebra would be on the anterior side, but Dr Zittel would rather regard those on the posterior aspect as referable to this segment of the column. In the Bijori stage of the Lower Gondwanas of India this group is

represented by *Gondwanosaurus;* while, if we may judge by a detached intercentrum which may belong to it, *Rhytidosteus*, of the Karoo system of South Africa, should also find a place here. The American Permian, in addition to *Trimerorhachis*, has also yielded *Zatrachys*, *Eryops*, *Acheloma*, and *Anisodexis*. *Eryops* includes very large species, in which the nares are widely separated and not placed at the extremity of the snout, and the thoracic plates are not sculptured.

Family Diplospondylidæ.—This family[1] is proposed by Dr Fritsch for the genus *Diplospondylus*, from the Permian of Bohemia, characterised by the embolomerous structure of the entire vertebral column, and the absence of pits on the skull. *Cricotus* (fig. 961), from the Permian of Illinois and Texas, appears to be an allied form, which Professor Cope makes the type of the family *Cricotidæ*.

Finally, it may be mentioned here that the genus *Ichthyacanthus*, from the Carboniferous of Ohio, which is frequently placed in the Microsauria, is described as having rhachitomous vertebræ.

Family Nyraniidæ.—The genus *Nyrania*, from the Permian of Bohemia, of which the skull is shown on an enlarged scale in figs. 824, 825 (pp. 902, 903), differs from *Archegosaurus* in that the palatines, in place of forming splints on the inner side of the maxillæ, are situated near the middle line, internally to the vomers and pterygoids, and would therefore seem to represent a distinct family. This arrangement of the bones of the palate is similar to that obtaining in the existing Caudata. Some of the genera noticed among the *Archegosauridæ*, in which the skull is unknown, may belong to this family.

Family Dendrerpetidæ.—This family, which may be taken to include the Brachiopina of Professor Miall, contains several genera, of which the precise serial position and full affinities are at present somewhat uncertain. The skull is parabolic, and marked by deep pits; the parasphenoid in the type genus has a short stem; and the teeth have irregular foldings at the base. The vertebræ were fully ossified, and may have been of the embolomerous type. The type genus *Dendrerpeton* is a medium-sized form occurring in the Carboniferous of Nova Scotia and the Permian of Bohemia, and characterised by the orbits being placed near the centre of the skull. Another group of genera, constituting the above-mentioned Brachiopina, appears to agree so closely with the type in cranial characters, that it may at least provisionally be included in the same family. The orbits are generally placed somewhat anteriorly. This group comprises *Brachyops*, known by a single skull from the Mangli stage of the Upper Gondwana system of India; *Micropholis* (*Petrophryne*),

[1] *Diplovertebridæ*, see note, p. 1027.

from the Karoo system of South Africa; *Bothriceps*, from the Lower Mesozoic of Australia; and *Rhinosaurus*, from the Jurassic of the Ural Mountains. There is frequently a *lyra* on the skull, but this

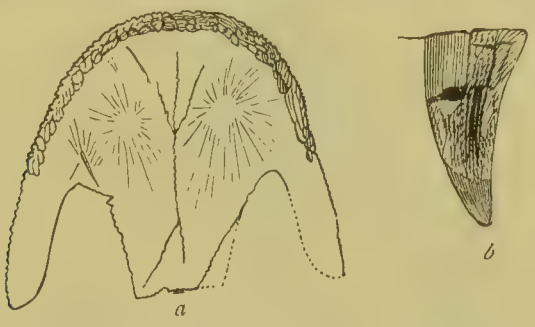


Fig. 962.—*a*, Oral view of palate, much reduced, *b*, Tooth, natural size, of *Baphetes planiceps*; from the Carboniferous of Nova Scotia.

is wanting in *Micropholis*, as in *Dendrerpeton*. It is probable that a young skeleton from the Lower Mesozoic Hawkesbury beds of New South Wales, described under the preoccupied name of *Platyceps*, belongs to *Bothriceps*.

Family Anthracosauridæ.—In this family the vertebral column is fully ossified in the adult; the teeth are deeply infolded; the mucous canals between the orbits and the nares form a lyre-shaped pattern known as the *lyra*; and the ventral surface of the body typically has a covering of bony scutes. The skull may be parabolic, but is usually triangular. This family may be divided into three subfamilies. The first, or *Baphetinæ*, is represented solely by the genus *Baphetes*, of the Carboniferous of Nova Scotia, which can only be provisionally placed in this family. It is only known by the imperfect skull (fig. 962), which is broad, and rounded anteriorly.

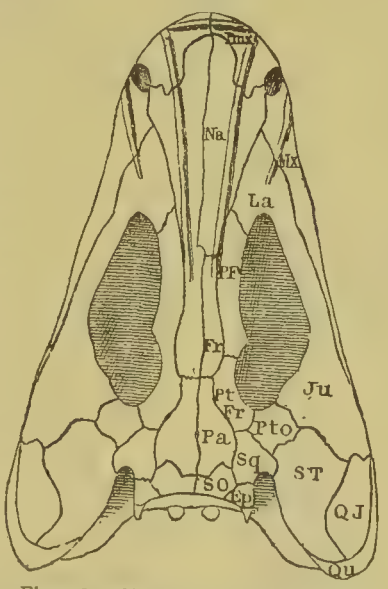


Fig. 963.—Upper view of the skull of *Loxomma Allmanni*; from the Carboniferous of Durham. Reduced. Letters as in fig. 958. (After Miall.)

In the *Loxommatinæ* (*Chauliodontia*), the members of the one genus *Loxomma* attain a large size, and are characterised by the triangular skull (fig. 963), which has large posterior projections, with the lyra forming two straight grooves, continued posteriorly as ridges. The teeth are compressed, large, and irregular, with the foldings deeper

than in the *Archegosauridæ*. The vertebral centra are disk-like, and may perhaps be embolomerous. *Loxomma* (fig. 963) occurs in England in the Carboniferous, but has also been recorded



Fig. 964.—Dorsal surface of the skull of *Anthracosaurus Russelli*; from the Carboniferous of England. One-sixth natural size. (After Atthey.)

from the Permian of Bohemia. The large size of the orbits is well shown in the figure; another characteristic feature being the absence of a postglenoidal process to the mandible. The ventral scutes are unknown, and if it be eventually found that these are wanting, this genus should perhaps form the type of a distinct family. In the typical subfamily *Anthracosaurinæ* the skull (fig. 964) is triangular, and characterised by the small size of the palatal vacuities; while the teeth are subcylindrical. The type genus *Anthracosaurus* occurs, as its name implies, in the Carboniferous, ranging from Britain to the Continent. One of the dermal ventral scutes is shown in fig. 965. The skull was also covered with scales or scutes; and it appears from one specimen that these scutes did not extend over the parietal foramen, which induces Dr Credner to consider that the Palæozoic Labyrinthodonts were provided with a functional parietal eye, of which an aborted rudiment persists in *Sphenodon*. The imperfectly



Fig. 965.—Scute of *Anthracosaurus*. (After Atthey.)

known *Dasyceps*, from the English Permian, is allied in cranial structure to *Anthracosaurus*. Moreover, some writers place in this family the imperfectly known genera *Platyops*, from the Permian of Russia, and *Macromerion*, from the corresponding strata of Bohemia.

Family Mastodonsauridæ.—The members of this family, together with some of the *Anthracosauridæ*, constitute the Euglypta of Professor Miall's classification, and may be regarded as the typical representatives of the order. They are distinguished from the latter family by the still more complex structure of the teeth; the stronger sculpture of the skull; and the absence of scutes on the ventral surface of the body. Large palatovomerine teeth (fig. 966) are placed on the inner side of the maxillary teeth, and there is a corresponding inner series of small teeth in

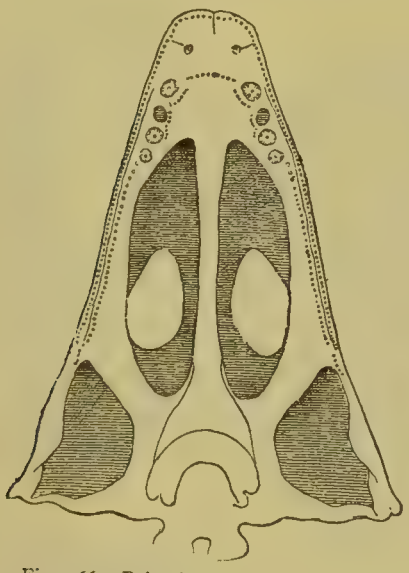


Fig. 966.—Palatal aspect of the cranium of *Mastodonsaurus giganteus*; from the Keuper of Würtemberg. Reduced. (After Miall.)



Fig. 967.—*Mastodonsaurus giganteus*. *a*, Dorsal aspect of skull, greatly reduced; *b*, tooth on a larger scale.

the mandible; while there is no bony ring in the sclerotic. The following features may be also noticed, although some of them are common to the typical *Anthracosauridæ*. The mandible has a large postglenoidal process, and the crowns of the teeth are conical. The palatines have the same position as in the *Archegosauridæ*. In the pelvis of the type genus the pubes are separate from the ischia, and do not enter into the formation of the acetabulum; and the sacral ribs form kidney-like disks. The centra or bodies of the vertebræ in the adult form disks which are fully ossified; but in the

young, as we infer from *Mastodonsaurus*, in which alone this feature has been observed, they were rhachitomous, as in the adult condition of the *Archegosauridæ*. The palatal vacuities were large and approximated, as is well shown in fig. 966. This family may be divided into two groups, according to the presence or absence of an inner articular buttress at the proximal extremity of the mandible. The group in which this buttress is present is represented by the type genus *Mastodonsaurus*, best known by the huge *Mastodonsaurus giganteus* (figs. 966, 967) of the Trias of Europe, which probably attained a length of seven or eight feet, and ranged from the Muschelkalk to the Rhætic. Besides other European Triassic species, this genus is also represented in the Lower Mesozoic (Maleri stage) of India by a form closely allied to *M. giganteus*, and by another in the Hawkesbury beds of New South Wales. Figure 968 shows the

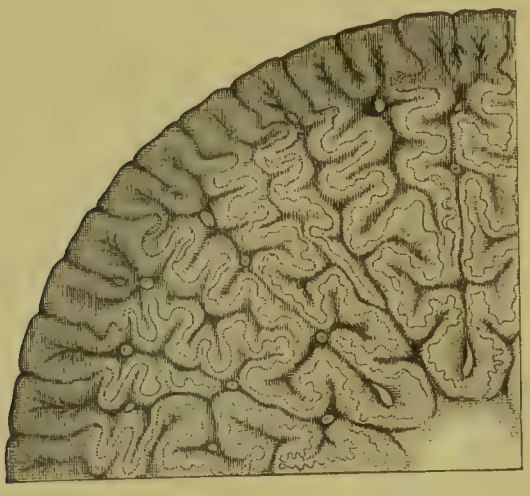


Fig. 968.—Transverse section of a segment of a tooth of *Mastodonsaurus giganteus*. Greatly enlarged. (After Owen.)

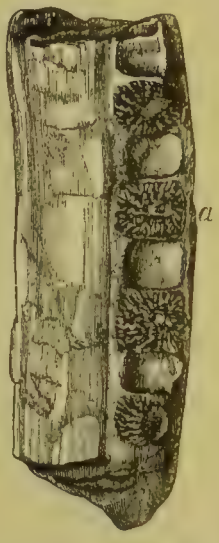


Fig. 969.—Fragment of jaw of one of the *Mastodonsauridæ*; from the Upper Gondwanas of India. *a* shows the section of a tooth.

structure of a transverse section of a segment of a tooth of this genus; the mode of attachment of the teeth to the jaw being exhibited in fig. 969. In the transverse section it will be observed that there is one set of sinuous linear interspaces communicating with the exterior, and a corresponding series (separated from each other by the dental wall) of sinuous processes from the central pulp-cavity. Other genera of this group are *Capitosaurus* (including *Cyclotosaurus*), from the Keuper of Germany; *Trematosaurus*, from the Bunter of the same country, distinguished by its more slender

skull; and the apparently allied *Gonioglyptus*, from the Panchet stage of the Lower Gondwanas of India. *Pachygonia* (fig. 952), of the latter deposits, may also be provisionally included in this group. From the Maleri stage of the Upper Gondwanas we have also a Labyrinthodont apparently closely allied to *Capitosaurus*, and thus indicating a precise parallelism in the evolution of the group in the Indian and European horizons. Here also we may perhaps place a small form described under the provisional name of *Glyptognathus*, from the Indian Panchets. *Metopias*, of the Continental Keuper and Rhætic, is distinguished from the preceding genera by the more anterior position of the orbits; *Labyrinthodon*, of the English Keuper, being probably allied. The second group is represented by *Diadetognathus*, of the Warwickshire Trias, in which the mandible has no inner articular buttress.

Of Uncertain Family.—Here may be mentioned the genus *Eosaurus*, founded upon large vertebral centra (fig. 970), from the

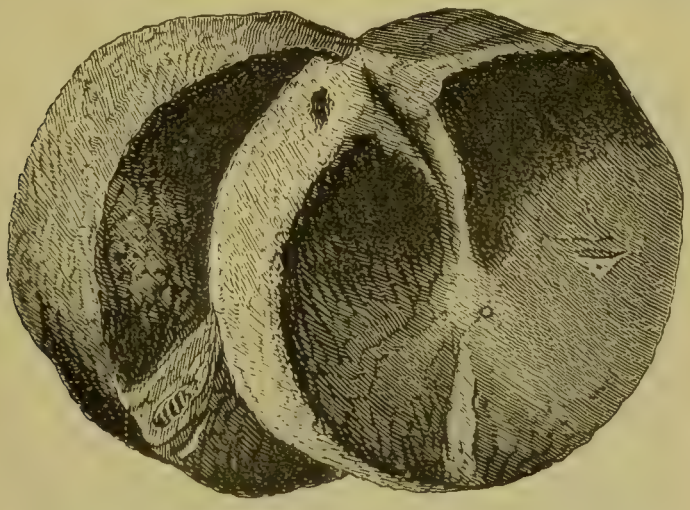


Fig. 970.—Two vertebral centra of *Eosaurus acadianus*; from the Carboniferous of Nova Scotia. (After Marsh.)

Carboniferous of Nova Scotia, which were regarded by Professor Marsh as belonging to an Ichthyosauroid Reptile, but which really indicate a large Labyrinthodont, perhaps referable to the *Mastodonsauridæ*.

Leaving out some ill-defined genera, mention must be made of *Pteroplax*, of the British Carboniferous, which was formerly classed next to *Batrachiderpeton*. The skull is elongated, and remarkable for the incomplete orbits; while it appears that many of the ordinary bones are wanting. The cranial bones have a pitted sculpture; and the vertebral centra are thick and fully ossified.

Labyrinthodont Footprints.—In the Bunter, or Lower Trias of Germany, and also in the Keuper, or upper division of the same system in Cheshire and Warwickshire, there are frequently found long series of the impressions of the feet of five-toed animals, which have generally been regarded as those of Labyrinthodonts, although it has been suggested by Professor Miall that some of them may be Dinosaurian. These footprints were described under the name of *Chirotherium*, on the supposition that they were of Mammalian origin; but in case this should prove incorrect the alternative name *Chirosaurus* was proposed, and since they are certainly Saurian, the





Fig. 970*bis*.—Footprints of *Chirosaurus Barthi*, from the Bunter sandstone of Hessberg, near Hildburghausen, Germany. Reduced.

latter name should be adopted. These impressions (fig. 970 *bis*) were made by Saurians in which the hind foot was much larger

than the fore foot, some of those of the hind foot having a length of eight inches. The absence of any known Dinosaurians from the Bunter is strongly in favour of the Labyrinthodont nature of these tracks; and it has been suggested that those described as *Chirosaurus Barthi* were made by *Trematosaurus Brauni* of the Bunter, the skull of which has a length of eight inches. If this should prove to be the case, the name *Trematosaurus* would have to yield to the earlier *Chirosaurus*. The largest tracks from the Keuper of Cheshire have been described as *C. Herculis*. Other tracks of feet from the Permian and Trias, which may be of Labyrinthodont origin, have been described under distinct names which it will be unnecessary to quote.

Order II. Apoda.—The remarkable limbless Cæcilians being unknown in a fossil state require no further mention.

Order III. Caudata.—In this order the body is elongate, and either lacertiform or anguiform, with a tail, and usually with two, but occasionally only one, pairs of limbs. The cranium lacks the postorbital, supratemporal, and supraoccipital bones of the Labyrin-

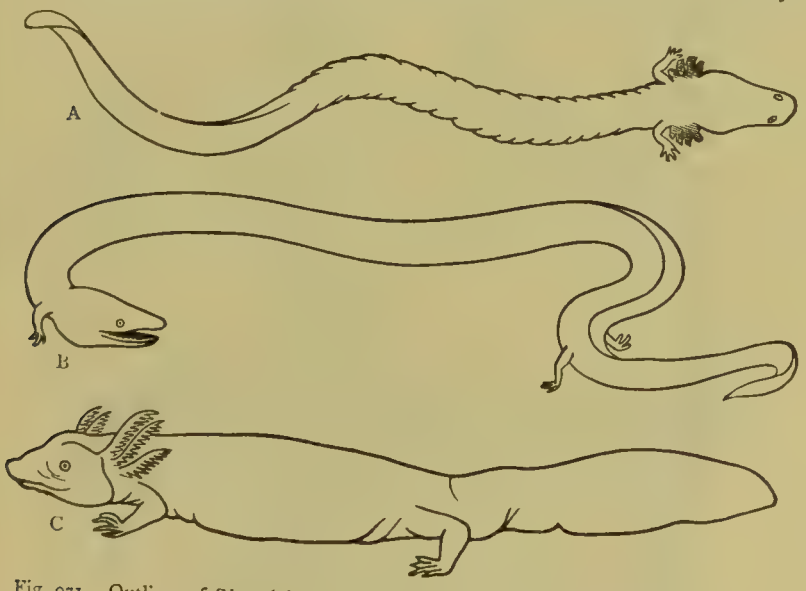


Fig. 971.—Outlines of *Siren* (A), *Amphiuma* (B), and *Menobranchus* (C). Reduced. (After Mivart.)

thodontia, and the palatines are approximated to the middle line, and placed internally to the vomers and pterygoids. The ribs are short, and the bodies of the vertebræ are either amphi- or opisthocœlous. The resemblance in the contour of the skull and the short ribs to the *Protritonidæ* suggests an affinity between the two groups; but the position of the palatines is rather indicative of a relationship with the *Nyraniidæ*.

Family Hylæobatrachidæ.—This family is formed for the

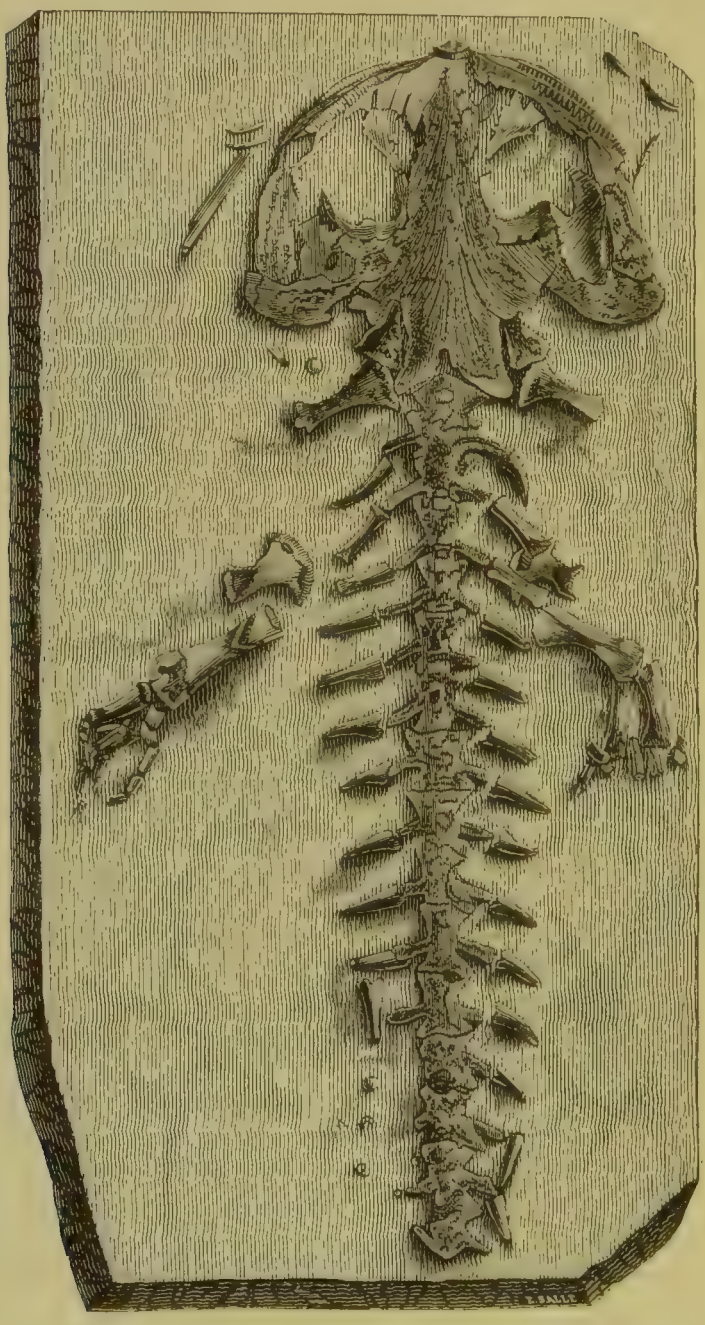


Fig. 972.—Anterior part of the skeleton of *Megalobatrachus Scheuchzeri*; from the Upper Miocene of Switzerland. Reduced.

reception of *Hylæobatrachus*, from the Wealden of Belgium, which appears to be an ancestral form allied to the *Proteidæ*, but distin-

guished by the presence of a maxilla, and of five digits to the feet.

Families Sirenidæ and Proteidæ.—*Siren* (fig. 971, A) and *Proteus*, together with *Menobranchus* (*ibid.*, C) are characterised by the persistent gills, the absence of maxillæ, the amphicœlous vertebræ, and the reduction of the number of the digits below five; *Siren* differing from the other two by the absence of pelvic limbs. No fossil representatives are known.

Family Amphiumidæ.—In this family the gills are shed, and maxillæ are present; but it agrees with the two last in the amphicœlous vertebræ, the cartilaginous carpus and tarsus, and the absence of eyelids. In the typical North American genus *Amphiuma* (fig. 971, B) the body is much elongated, and the limbs are very short. Another American genus is *Menopoma*, allied to which is *Megalobatrachus* (*Cryptobranchus* or *Sieboldia*), typically represented by the Gigantic Salamander (*M. maximus*) of China and Japan, and in which we may probably include the large Salamander (fig. 972) from the Upper Miocene of Switzerland, originally regarded as human, and subsequently described under the name of *Andrias*.

Family Salamandridæ.—The true Salamanders lose their gills, although there are instances, as in *Amblystoma* (*Siredon*), where they persist in some individuals. Eyelids are present; the vertebræ are generally opisthocœlous; and the carpus and tarsus more or less ossified. This family is now represented in Europe by the Salamanders (*Salamandra*) and Newts (*Molge* or *Triton*). In a fossil state the existing *Molge cristata* (fig. 973) occurs in the Norfolk

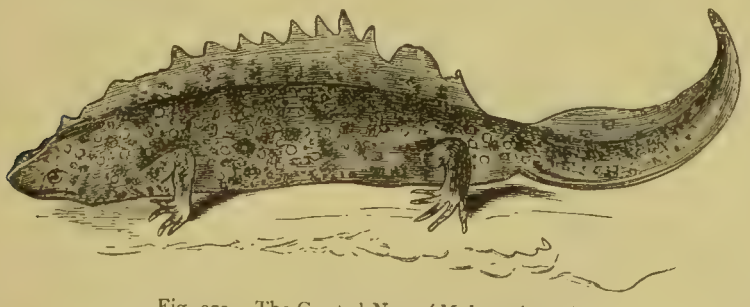


Fig. 973.—The Crested Newt (*Molge cristata*).

Forest-bed, and representatives of this genus have also been recorded from the Middle and Lower Miocene of the Continent. The latter deposits have also yielded remains referred to *Salamandra*, while the name *Chelotriton* has been applied to an imperfectly known form from the Lower Miocene of St Gérand-le-Puy, in Allier. *Heliarchon*, from the corresponding strata of Rott, near Bonn, is allied to *Salamandra*, and may not improbably be identical with *Chelotriton*. *Megalo-*

triton is a large form from the Upper Eocene Phosphorites of Central France.

Order IV. Ecaudata.—The Frogs and Toads form a highly specialised order of comparatively late origin. In the adult the body is short, destitute of a tail, and furnished with four limbs, of

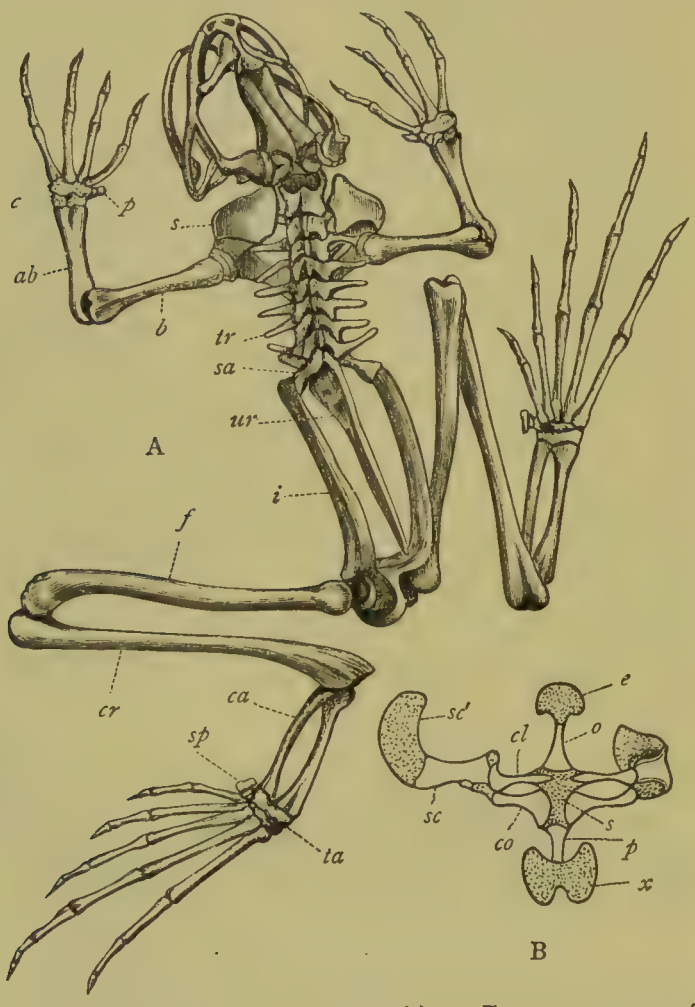


Fig. 974.—A, Skeleton of the Frog (*Rana temporaria*): *tr*, Transverse processes of vertebræ; *sa*, Sacrum; *ur*, Urostyle; *i*, Ilium; *s*, Suprascapula; *b*, Humerus; *ab*, Radius and ulna; *c*, Carpus; *p*, Pollex; *f*, Femur; *cr*, Tibia and fibula; *ca*, Calcaneo-astragalus; *ta*, Tarsus; *sp*, Prohallux. B, Pectoral arch and sternum of Frog (after Gegenbaur). The dotted parts represent cartilages. *e*, Episternum; *o*, Omosternum; *p*, Body of the sternum; *x*, Xiphisternum; *sc'*, Suprascapula; *sc*, Scapula; *cl*, Precoracoid; *co*, Coracoid; *s*, Epicoracoid.

which the pelvic pair is the longer, and adapted for leaping. There are no gills. The skull is short and wide, with enormous orbits, and the parietals confluent with the frontals. A peculiar ossification known as the *girdle-bone* encircles the skull in the ethmoidal region, and there is a predentary ossification in the mandible. The pre-

sacral vertebræ are few in number, and generally procœlous; there is but one vertebra in the sacrum; the vertebral column terminates in a long urostyle (fig. 974, *ur*), and there are usually no separate ribs. The ilia (*i*) are prolonged backwards, so as to throw the acetabulum far behind the sacrum; the radius and ulna (*ab*), and the tibia and fibula (*cr*) are respectively fused together; and the calcaneum and astragalus (*ca*) greatly elongated. There are five digits in each foot, with an additional ossicle (*sp*) in the pes which apparently represents a prohallux.

According to the presence or absence of the tongue this order is divided into the suborders Phaneroglossa and Aglossa; the latter containing only the two families *Dactylethridæ* and *Pipidæ*. The Phaneroglossa are subdivided into the *Firmisternine* and *Arciferine* series; the former characterised by the epicoracoids forming a band connecting the coracoids (fig. 974, B), and the latter by the overlapping of the epicoracoids. Since fossil forms are but very imperfectly known, only brief mention will be made of those families which have fossil representatives.

Family Discoglossidæ.—Commencing with the *Arciferine* series of the Phaneroglossa the present family is distinguished from those that follow, and thereby approximates to the Newts, in having opisthocœlous vertebræ and rudimentary ribs. The European genus *Bombinator* is probably represented in the Upper Miocene of Switzerland; although some writers have referred the fossil species to a distinct genus under the name of *Pelophilus*. Opisthocœlous vertebræ from the Middle Miocene of Sausan, in Gers, may belong either to *Bombinator* or to the other existing European genus *Alytes*. *Bufavus*, from the Middle Tertiary of Italy, is said to present many affinities to the present family, but in the absence of ribs approximates to the one that follows.

Family Pelobatidæ.—This small family is characterised by the presence of teeth in the upper jaw; the absence of ribs; and the unexpanded extremity of the sacral rib. The vertebræ are usually procœlous, although occasionally opisthocœlous. The existing genus *Pelobates* occurs in the Miocene of Sausan, while the imperfectly known *Protopelobates*, from the Miocene of Bohemia, may belong either to this or the next family.

Family Palæobatrachidæ.—This extinct family has teeth in the upper jaw; no ribs; expanded ribs to the sacral vertebra; and procœlous vertebræ. The single genus *Palæobatrachus* (*Probatrachus*) is now known to have been widely distributed over the Continent during the Lower Miocene; more than a dozen species having been described.

Family Bufonidæ.—The true Toads are characterised by the total absence of teeth and dorsal ribs; the expanded extremities of

the ribs of the sacral vertebra; and the procœlous vertebræ. Of the type genus *Bufo* existing species occur in the European and Indian Pleistocene. *B. Gessneri*, of the Upper Miocene of Switzerland, appears closely allied to the living *B. viridis*, although, together with another species from the same beds, it has been made the type of *Palæophrynus*. Dr Filhol records the type genus from the Upper Eocene Phosphorites of France.

Family Cystignathidæ.—This family represents the Frogs in Tropical America and Australia. The huge *Ceratophrys cornuta*, or Horned Frog of Brazil, occurs in the cave-deposits of that country; while *Latonia*, of the Swiss Miocene, appears to be a closely allied if not identical genus, characterised by the smaller head, more slender pelvis, shorter manus, and longer pes. A somewhat similar instance of distribution occurs in the case of the Chelonian *Chelydra*. The cave-deposits of Brazil have also yielded remains of the existing *Leptodactylus pentadactylus*.

Family Ranidæ.—In the *Firmisternine* series the True Frogs have teeth in the upper jaw, and the extremities of the sacral ribs are not expanded. *Rana* is represented by existing species in the Norfolk Forest-bed, and probably in the Pleistocene of Sardinia; it probably also occurs in the Miocene of Sausan and other places on the Continent; and has been described from the Upper Eocene Phosphorites of Central France, where the one known species seems to be allied to the Indian *R. tigrina*. The Oriental genus *Oxyglossus*, in which there are no vomerine teeth, is found in the Eocene of Bombay. *Ranavus*, from the Middle Tertiary of Italy, may perhaps belong to this family, although it is said to show affinity to the *Pelobatidæ;* and we may here mention the imperfectly known *Amphirana*, *Batrachus*, and *Protophrynus* of the Lower Miocene of France, although their family position may be doubtful.

LITERATURE OF AMPHIBIA.

1. Atthey (T.)—"On *Anthracosaurus Russelli*." 'Ann. Mag. Nat. Hist.,' ser. 4, vol. xviii. (1876).
2. Baur (G.)—"Die alteste Tarsus (*Archegosaurus*)." 'Zool. Anzeiger.' No. 216. (1886).
3. Burmeister (H.)—"Die Labyrinthodonten aus dem Bunten Sandstein im Bernburg." 1849.
4. Cope (E. D.)—"Description of Extinct Batrachia and Reptilia from the Permian of Texas." 'Proc. Amer. Phil. Soc.,' vol. xvii. (1878).
5. —— "On the Intercentrum of the Terrestrial Vertebrata." 'Trans. Amer. Phil. Soc.,' vol. xvi. (1886).
6. —— "Synopsis of Extinct Batrachia from the Coal-Measures." 'Geol. Surv. of Ohio, vol. ii., Palæontology' (1875).

7. COPE (E. D.)—"The Batrachia of the Permian of North America." 'American Naturalist,' vol. xviii. (1884).
8. CREDNER (H.)—"Die Stegocephalen aus dem Rothliegenden des Plauen'schen Grundes bei Dresden." 'Zeitschr. deutsch. geol. Ges.,' vols. xxxiii.-xxxviii. (1881-86).
9. DAWSON (W.)—"Acadian Geology." 2d ed. 1867.
10. —— "Air-breathers of the Coal-Period." 1863.
11. DOLLO (L.)—"Note sur le Batrachien de Bernissart." 'Bull. Mus. R. Hist. Nat. Belg.,' vol. iii. (1884).
12. EMBLETON (E.) and ATTHEY (A.)—"On the Skull and some other Bones of *Loxomma Allmanni*." 'Ann. Mag. Nat. Hist.,' ser. 4, vol. xiv. (1874).
13. FRAAS (E.)—"Die Labyrinthodonten der schwäbischen Trias,"—'Palæontographica,' vol. xxxvi. (1889).
14. FRITSCH (A.)—"Fauna der Gaskohle und der Kalksteine der Perm-formation Böhmens." Prague (1883-86).
15. GAUDRY (A.)—"Les Enchaînements du Monde Animal, &c.—Fossiles Primaires." Paris (1883).
16. —— "Les Reptiles de l'Epoque Permienne aux Environs d'Autun." 'Bull. Soc. Géol. France,' ser. 3, vol. vii. (1878).
17. —— "L'Actinodon." 'Archiv. Mus. Hist. Nat., Paris,' vol. x. (1887).
18. HUXLEY (T. H.)—"New Labyrinthodonts from the Edinburgh Coal-field." 'Quart. Journ. Geol. Soc.,' vol. xviii. 1862.
19. —— "Description of Vertebrate Remains from the Jarrow Colliery, Kilkenny." 'Trans. Roy. Irish Academy,' vol. xxiv. (1867).
20. —— "Vertebrate Fossils from the Panchet Rocks." 'Palæontologia Indica (Mem. Geol. Surv. Ind.),' ser. 4, vol. i. (1865).
21. LYDEKKER (R.)—"The Bijori Labyrinthodont." 'Palæontologia Indica,' ser. 4, vol. i. (1885).
22. MIALL (L. C.)—"Report on the Labyrinthodonts of the Coal-Measures." 'Rep. Brit. Assoc.' 1873.
23. —— "Report on the Structure and Classification of the Labyrinthodonts." *Ibid.* 1874.
24. OWEN (R.)—"Fossil Reptilia discovered in the Coal-Measures of South Joggins, Nova Scotia." 'Quart. Journ. Geol. Soc.,' vol. xviii. (1862).
25. —— "On a Labyrinthodont Amphibian (*Rhytidosteus*) from the Cape of Good Hope." *Ibid.*, vol. xl. (1884).
26. PORTIS (A.)—"Resti di Batraci Fossili Italiani." 'Appunti Paleontologi,' part 2. Turin (1885).
27. ZITTEL (K. A.)—"Handbuch der Palæontologie," Abth. i., vol. iii., part 2. Munich (1888).

CHAPTER LII.

CLASS REPTILIA.

General Structure.

With the Reptiles we enter upon the consideration of the first of two classes which, from the possession of many common characters, have been brigaded together by Professor Huxley under the name of Sauropsida. The name Monocondylia had, however, been previously proposed by Hæckel for these two classes, and some writers consequently prefer to use this term. These two classes are the Reptilia and the Aves, or Birds; and although recent research has shown the existence of a close affinity between the more generalised Reptilia and the Amphibia, and thus with the Mammalia, yet it has in no wise tended to interfere with this association. It should, however, be observed that since it is probable the Reptiles have taken origin from forms more or less nearly allied to some of the earlier Amphibia, with which we are at present acquainted, it is obvious that there must once have existed animals in which the characteristic features of the true Amphibia and the Reptilia were more or less blended, and that the practicability of drawing a distinction between the two classes is thus (as in other cases) more or less due to the imperfection of our knowledge. With this proviso, and bearing in mind that some of the more generalised forms with which we are even now acquainted may not conform in every detail with the undermentioned characters, the Reptilia as a whole, together with the Birds, may be distinguished from the preceding classes on the one hand, and from the Mammalia on the other, by the following features.

Epidermal structures in the form of scales or feathers are generally present, but there are never hairs. The vertebræ, which are ossified, usually have no epiphyses.[1] The basioccipital, with one

[1] These are present in some of the Sauropterygia among Reptiles, and in Parrots among Birds.

or two exceptions, is completely ossified; and, in conjunction with the exoccipitals, forms the single occipital condyle by which the cranium articulates with the atlas vertebra. In the adult there is, as a rule, no distinct parasphenoid [1] on the base of the skull. The mandibular rami respectively consist of an articular cartilage-bone and of several membrane-bones; the articular bone being connected with the squamosal of the cranium by a quadrate. The apparent ankle-joint, in all existing forms, is situated between the proximal and distal rows of the tarsus; and not, as in the Mammalia, between the tibia and astragalus. Gills are never developed during any period of life; the embryo is provided with an amnion and an allantois; and there are no mammary glands. As the palæontologist will not have to deal with the other distinctive features derived from the soft parts, it will not be necessary to refer to them in this work.

Regarding the features of Reptiles as distinct from Birds, the approximation between the two classes is so close that it is difficult to give any very clear diagnosis. In the present class, however, the epidermal structures take the form of overlapping horny scales (Squamata), or of shields with their edges in apposition (Chelonia); while dermal bony scutes are very frequently developed. The vertebræ may be amphicœlous, opisthocœlous, or procœlous; but the centra of the cervicals do not have cylindroidal and saddle-shaped articular surfaces. The sacral vertebræ, when present, have broad expanded ribs for articulation with the ilia. The sternum in existing forms is rhomboidal; and the ribs may be attached to it by a backward median process, or processes. The interclavicle is never fused with the clavicles. There are more than three digits in the manus; and never less than three in the pes. Except in the Theromorous branch, the three elements of the pelvis as a rule remain distinct; [2] and there is apparently no known instance, except one which may probably be regarded as a pathological peculiarity, of the fusion of the metatarsals, or of their union with the distal row of the tarsus. In all living Reptiles there is both a right and a left aortic arch; the arterial and venous circulations are at best but imperfectly separated; and the blood is cold.

Since the various orders of Reptiles differ so greatly from one another in structure it will be advisable to make most of our observations on their osteology under those several headings. As a rule, however, the bones of the cranium retain the general arrangement observable in the Amphibia; there being distinct postorbital or postfrontal ossifications; usually either one or two temporal arcades; and distinct post-, supra-, and infratemporal fossæ, as defined in the

[1] Dr Baur suggests that this bone may be present in *Palæohatteria*.

[2] They are anchylosed in *Testudo atlas* of the Indian Siwaliks, and also in *Miolania*.

introductory chapter (p. 904). The bones of the skull are of a dense ivory-like structure, and in most cases their sutures persist; although in certain groups the premaxillæ, frontals, and parietals may respectively unite. A new element—the *transverse*, or *transpalatine*, bone (fig. 1089, *Ts*)—connecting the maxilla with the pterygoid, appears; but this is absent in the Chelonia and some Ophidia. An *epipterygoid*, or *columella*, connecting the pterygoid with the parietals, may also be present. A parietal foramen may or may not be present; and the occipital condyle is usually placed at the hinder extremity of the cranium. The apertures of the external nares may be terminal, as in the Amphibia, or approximated to the orbits, as in the Birds; and the bones of the palate may develop a floor underlying the narial passage and thus cutting it off from the mouth. As a general rule the mandibular symphysis is not anchylosed; but this takes place in the Chelonia and Ornithosauria. The quadrate may be either loosely or immovably attached to the cranium.

The dentition is usually well developed, and the teeth of different parts of the jaws are occasionally more or less differentiated; although there is no known instance where they are implanted by double roots, or where their crowns have deep infoldings of enamel. They may be present not only in the jaws, but also upon the palatine, pterygoid, and more rarely the vomer. In other instances, however, teeth may be entirely wanting, and the jaws simply ensheathed in horn. The teeth may be anchylosed to the outer side of the jaws, when the dentition is termed *pleurodont* (fig. 975); or to their summits, when the term *acrodont* is applied; or they may be set in a groove, with or without anchylosis to the bone; or, finally, they may be placed in distinct sockets, when the dentition is said to be *thecodont*. The teeth on the palate are generally anchylosed to the subjacent bones. There is usually a continuous succession of teeth developed throughout life; the new teeth coming up beneath those in use and absorbing the base of the crown, as is shown in the teeth of the Gharial represented in fig. 1090. In shape the teeth of Reptiles present great variation; but a very common type, from which many of the variations are derived, consists of a more or less laterally-compressed and recurved cone, with fore-and-aft cutting edges, or *carinæ*, which may or may not be serrated (fig. 976). Occasionally, however, the teeth of the jaws or those of the palate may have nearly flat crowns adapted for crushing (fig. 986).

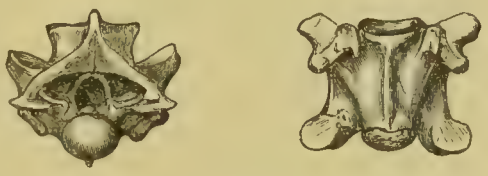


Fig. 975.—Inner view of the left ramus of the mandible of *Iguana*.

When both pairs of limbs are present the vertebral column is differentiated into cervical, dorsal, lumbar, sacral, and caudal regions; and the vertebræ themselves are invariably ossified, although in some primitive types a small notochordal canal may perforate their centra. In a large number of existing forms the majority of the centra are procœlous; but they are amphicœlous in many fossil and a few existing types; while among the Dinosauria and Chelonia an opisthocœlous type is common in parts of the series. In all cases there is an intercentrum between the skull and the atlas; which may either form the inferior ring of the latter, or, when the centrum of the atlas is separate (Ichthyopterygia), may be of the normal wedge-like form. In some groups additional articulations may be developed on the arches of the trunk vertebræ, taking the form of a wedge-shaped process, or *zygosphene*, fitting into a corresponding cavity, or *zygantrum* (fig. 977). The transverse processes of the dorsal vertebræ may be either long (fig. 1058) or very short (fig. 977); and the ribs may articulate either by a single head with the transverse process, or by two heads to different portions of the same process, or by one articulation to the latter and by another to a facet on the arch or the centrum; there being great variation as to the position of the transverse processes and rib-facets in different groups, and also in the different parts of the column of a single animal. Occasionally the ribs articulate at the junction of two vertebræ. Chevron-bones are generally present in the tail; and intercentra may be retained. No living Reptile with limbs has less than two sacral vertebræ, and in certain extinct forms the number may be increased to five or six. In nearly all Reptiles the tail is well developed. The ribs may have uncinate processes. In many existing forms the sternum, which may be ossified, is rhomboidal, and may have the last pair of ribs attached to a backward median process. Its structure in many fossil groups is not known, but according to Professor Marsh's interpretation some of the Dinosaurs had paired sternal ossifications, corresponding to the two centres from which the sternum develops in the Ratite Birds. Abdominal ribs may be developed in the parietes of the ventral



Fig. 976. — Profile and lateral views of the crown of a tooth of a Dinosaur (*Massospondylus*), with the marginal serrations magnified; from the Mesozoic of India.



A B

Fig. 977.—Posterior (A) and hæmal (B) aspects of a dorsal vertebra of a Snake. The cavities in A on the sides of the neural canal are the zygantra.

surface of the abdomen, and consist of a median and two lateral moieties.

In the pectoral girdle the scapula is generally a more or less elongated bone, with an expansion at its glenoidal extremity. A separately ossified precoracoid exists only in the Anomodonts (fig. 978 *bis*), this bone being in other cases fused either with the scapula, as in the Chelonia (fig. 1008), or with the coracoid, as in Lizards (fig. 830); the fontanelle which frequently occurs in the latter instances apparently marking the original line of separation of the two bones. The coracoid may vary in shape from a long spatulate form (Chelonia) to that of a cheese-cutter (Dinosauria).

The humerus has in many cases no distinct distal condyles (trochleæ), although these are well developed in the Anomodonts, Lizards, and Sphenodon. In the more generalised types there is frequently an entepicondylar foramen to this bone, but in the Lizards and Chelonians the foramen or groove is ectepicondylar; and in a few instances both foramina are present. The radius and ulna always remain distinct. The number of bones in the carpus varies considerably in the different orders, but in *Sphenodon* alone among existing forms is there more than a single centrale; the five distal bones (carpalia) may be all distinct from one another (fig. 829). In the pelvis of the majority of reptiles, the ilium is produced more behind than in front of the acetabulum (fig. 831), and the latter is more or less completely closed by bone; while the pubis (fig. 831) is directed downwards and forwards, and, like the ischium, usually meets its fellow in a ventral symphysis. Among the Dinosaurians, however, the pelvis may be of a Bird-like type, when the pubes do not form a symphysis. Usually the obturator interval forms an open notch; but by the ventral union of the pubis and ischium of the same side this notch may be converted into a foramen. The femur among the Dinosaurs may develop an inner trochanter; and, except in some Ornithosauria, the fibula always remains distinct from the tibia. As in the carpus, the elements of the tarsus vary considerably in the different groups, but the centrale (navicular) is only present in the Anomodontia, the Proterosauria (according to Professor Seeley), one family of Chelonians, and the Ichthyopterygia; while, with the exception of a few extinct types, and perhaps the existing Chelonia, the fourth and fifth tarsalia in all land forms coalesce into a single bone, which supports the fourth and fifth metatarsals. In certain groups—such as the Anomodontia and many of the Chelonia (fig. 829)—the number of phalangeals in the feet of pentedactylate forms may be the same as in Mammals, or 2, 3, 3, 3, 3—the digits being reckoned from the first to the fifth. In Lizards, however, and their allies the number of phalangeals is usually 2, 3, 4, 5, 3 in the manus, and 2, 3, 4, 5, 4 in the pes.

The same numbers obtain in some Dinosauria; but in existing Crocodilia, in which the fifth digit of the pes is aborted, the numbers are 2, 3, 4, 4, 3 and 2, 3, 4, 4. Among the Sauropterygia and in the Ichthyopterygia the number of phalangeals is greatly increased. In a large number of forms the tail is long; but it is generally short in the Anomodontia, Sauropterygia, and Chelonia.

As regards the classification of Reptiles, scarcely any two writers agree as to the number of orders into which the class should be divided, and still less as to their mutual relations, and the larger groups under which these orders may be arranged. There is indeed but little difficulty in regard to existing forms, in which the few orders have become more or less sharply differentiated; but when we go back to the early part of the Mesozoic epoch, we find that nearly all the orders into which the class has been divided show such signs of passing more or less completely into one another, that it is quite impossible to exhibit their true relationship by any system of linear classification. The best arrangement seems, therefore, to group the orders under a series of diverging branches, which will approximate to one another more and more as we recede in time—until, about the epoch of the Lower Permian or possibly the Carboniferous, it is probable that, if we knew all the extinct forms, these branches would be seen to originate either from one, or from but very few parent stems. In regard to the number of these branches, there is still room for a considerable amount of discussion; almost the only absolutely sure ground that we can feel being the association of the three orders forming the Archosaurian branch. To a less extent the same remark applies to the orders themselves; and the right to ordinal distinction of the Proterosauria is not admitted by many writers, while there is not perfect accord in regard to that of the Rhynchocephalia. The provisional arrangement which is adopted in this work is a modification of one recently proposed by Dr G. Baur, of New Haven, and may be tabulated as follows, viz. :—

Theromorous Branch.	Order	1. Anomodontia.
Synaptosaurian	"	2. Sauropterygia.
	"	3. Chelonia.
Streptostylic	"	4. Ichthyopterygia.
	"	5. Proterosauria.
	"	6. Rhynchocephalia.
	"	7. Squamata.
Archosaurian	"	8. Dinosauria.
	"	9. Crocodilia.
	"	10. Ornithosauria.

It may be added that the close approximation to the Amphibia presented by the earlier members of several of these branches

suggests the idea that Reptiles may have been derived from the Amphibians by more than one line of descent.

The Reptiles in the passage of time have suffered more severely than any other class of the Vertebrata, only four of the above-mentioned ordinal groups—viz., the Chelonia, Rhynchocephalia, Squamata, and Crocodilia—now existing; and the second of these being represented only by a single genus with two species. There is some doubt as to the earliest known appearance of the class, since it has been thought that *Mesosaurus* (*Stereosternum*) may be of Carboniferous age, but it is more probably Permian. In undoubted Permian we have the Proterosauria, many of the European Anomodonts, and the Rhynchocephalian genus *Palæohatteria;* while many of the American Anomodontia occur in strata which are referred by the Transatlantic geologists to that period. With the advent of the Trias we find all the orders, with the exception of the Ornithosauria and Squamata, more or less fully represented. And while the former order makes its appearance in the succeeding Lias, we have at present no traces of the latter till the topmost Jurassic. The class reached, however, its zenith of development in the Jurassic and Cretaceous epochs; the greatest number of huge aberrant forms being characteristic of the later part of the former and the earlier part of the latter epoch. Although the one existing Rhynchocephalian genus is closely allied to Triassic forms, yet we have no instance among Reptiles of the existence of a genus right up from that period to the present day, as we have in *Ceratodus* among the Pisces, thus indicating that the higher we ascend in the scale of organisation, the more rapid is the change of types—the same law being exemplified by the occurrence of existing species of Reptiles among the totally extinct Mammals of the Indian Siwaliks.

CHAPTER LIII.

CLASS REPTILIA—continued.

Orders Anomodontia, Sauropterygia, and Chelonia.

Theromorous Branch. — The Reptiles included in this branch or alliance may, for the present at least, be arranged in a single order, although some writers would prefer to regard the suborders into which this order is here divided as of ordinal importance. The most remarkable features found in this order are the resemblance on the one hand to the Labyrinthodont Amphibia, and on the other to the Monotreme Mammals.

Order I. Anomodontia.—This order, which is equivalent to the Theromora (Theromorpha) of Professor Cope, presents the following characteristic features. The body is lacertiform, and the limbs are adapted for walking. The skull is comparatively short, with a fixed quadrate, a parietal foramen, either one or two temporal arcades, and large nasals; in the palate the pterygoids meet together in front of the basisphenoid, which they also join, but diverge anteriorly; while the palatines are generally small, and placed internally to the pterygoids, as in Mammals. When the temporal arcade consists of only a single chain of bones, it is a squamoso-maxillary one (p. 904). The dentition is thecodont, but the teeth may be anchylosed to the bone. The vertebræ have amphicœlous and in some cases notochordal centra; the dorsals carrying long transverse processes, and the ribs articulating by double heads in the anterior region of the trunk. As a rule abdominal ribs appear



Fig. 978.—The palmar aspect of the left humerus of *Ptychosiagum Murrayi*; from the Karoo system of South Africa. Half natural size. *a*, Entepicondylar foramen with the bridge broken away. (After Huxley.)

to be absent. An interclavicle, clavicles, and precoracoids are present, and a sternum was probably always developed. The scapula (fig. 978 *bis*) has an acromial process with which the precoracoid articulates. The humerus (figs. 978, 982), is characterised by its well-developed distal condyles, and the invariable presence of an entepicondylar foramen; while its delto-pectoral crest is generally much developed. In the pelvis the pubis is placed entirely in advance of the ischium, to which it is completely united, with the presence in some forms of a small fontanelle representing the obturator foramen. The ilium may have almost its whole body in advance of the acetabulum. The tarsus has one centrale; and the phalangeals of the manus and pes are typically 2, 3, 3, 3, 3 in number, as in Mammals, the whole structure of the foot being likewise of a Mammalian type.



Fig. 978 *bis*.—Lateral aspect of the cartilage bones of the right side of the pectoral girdle of a Dicynodont; from the Karoo system of Africa. *sc*, Scapula; *a*, Acromial process of do.; *p.cor*, Precoracoid; *cor*, coracoid; *gl*, Glenoid cavity. Half natural size.

This order appears to be confined to the Permian and Trias. It has been considered that the Anomodonts are the parent stock not only of all other Reptiles (with the possible exception of the Ichthyopterygia), but also of all Mammals. Later researches do not, however, altogether countenance this view, although there can be no doubt that they are closely allied to the parent stock of Mammals. Recent observations have indeed shown pretty conclusively that this order is directly descended from the Labyrinthodont Amphibians, and more especially from the Archegosaurian family. Thus in the small size or absence of the obturator foramen in the pelvis the entire order shows most decided affinities to that group; while in the small size of the coracoid of some forms, in the presence of a distinct precoracoid (epicoracoid), of very distinct condyles to the humerus, of the centrale in the tarsus, and also in the number of phalangeals, it has characters common both to the Labyrinthodonts and the Monotremes, which are not found together in any other group of Reptiles. These three groups also resemble one another in the non-development, as a general rule, of abdominal ribs; while signs of affinity between them are shown by the shortness of the tail, and the large

size of the exoccipital elements of the occipital condyle in the present order. In the presence of an entepicondylar foramen to the humerus the Anomodonts agree with Rhynchocephalians, Sauropterygians, and Mammals. In many cases (fig. 978 *bis*) the precoracoid forms a large plate-like bone suturally united with the whole of the anterior border of the coracoid, and also articulating largely with the acromial process of the scapula; thus exhibiting a parallelism between the structure of the pectoral and pelvic girdles found in no other reptiles. The above features, together with certain points in the structure of the palate mentioned below, suggest very strongly the descent of the Monotreme Mammals from the same primitive stock as that which gave rise to the Anomodonts. If, moreover, Dr Baur is right in considering that this order does not include the direct ancestors of Mammals, it would appear that the development of its more specialised representatives has followed a course in some respects parallel to that of Mammals.

Suborder 1. Pariasauria.—This suborder includes the most generalised members of the order, which make the nearest approach to the Amphibia. The cranium is at once characterised by the roofing over of its postero-lateral or quadratic region, after the Labyrinthodont manner, by the postorbital, squamosal, and opisthotic bones. Typically the palate, which approximates to an Amphibian type, and has been compared to that of *Nyrania* (fig. 825), apparently has no flooring of the nasal passage to form secondary posterior nares. The skull also has two temporal arcades, and the external surface of the cranial bones is frequently sculptured, as in the typical Labyrinthodonts. The vertebral centra retain a notochordal canal; the number of sacral vertebræ was limited to two, of which only one supports the ilium; and intercentra may be present. The pelvis is of a Labyrinthodont type, the ilium forming a triangular plate elongated in a direction oblique to the axis of the sacrum, with which it articulates obliquely; and there being no obturator foramen between the pubis and ischium. The humerus probably belonging to this group differs from that of other Anomodonts in the slight expansion of the extremities, and in that the lower aperture of the entepicondylar foramen opens on the distal surface of the bone.

Family Pariasauridæ.—The type genus *Pariasaurus* occurs in the Beaufort beds of the Karoo system of South Africa, of which the vertebrate fauna presents a Triassic facies. The best known species (*P. bombidens*) attains the dimensions of a large crocodile; and, with the unfortunate exception of the limbs, the entire skeleton is known, and has been described by Professor Seeley. In addition to the sculpture on the bones of the skull, mucous canals, like those of the Labyrinthodonts, are also present. The teeth are of uniform size, and, although anchylosed to the bone, are set in distinct sockets,

and were replaced after the Crocodilian manner; their crowns being somewhat compressed and grooved. The premaxillæ appear to have been small, as in the Amphibia. There are 29 vertebræ, of which 18 are presacral, and two are anchylosed together to form a sacrum; while wedge-shaped intercentra are also present. The neural spines are extremely short, and the centra of the dorsal vertebræ are very small in proportion to their arches; and only the first sacral vertebra supports the ilia of the pelvis. Small ribs are present in the caudal region; and there was probably a dermal armour.

Professor Seeley concludes that this very remarkable and Amphibian-like Reptile is a direct descendant from the Labyrinthodonts; the chief affinities to that group being displayed in the characters of the skull; in the notochordal canal, and the large arches of the vertebræ; in the support of the pelvis by a single vertebra; as well as in the characters of the pectoral and pelvic girdles. The latter features, together with the general structure of the palate, being identical with those of typical Anomodonts, there appears every reason for referring this family to a suborder of that group.

The genus *Propappus* is founded upon a humerus, from the Karoo system of the Cape, of the above-mentioned type, and there is no direct evidence of its distinctness from *Pariasaurus*. The innominate bone referred to *Dicynodon leoniceps* probably belongs, however, to *Propappus*, which may thus be entitled to stand. The pelvis and sacrum described under the name of *Dicynodon tigriceps* also seem to indicate a member of this suborder, since the ilium is of the same type as in *Pariasaurus*, and is connected with the sacrum by only a single rib, while there is no obturator foramen.

From the general resemblance of its skull to that of *Pariasaurus*, we may refer to this family the genus *Anthodon*, of the South African Karoo system, which, although originally regarded by Sir R. Owen as a Dinosaur, must be included in the present order. It agrees with *Pariasaurus* in the roofing over of the quadratic region, and the continuous replacement of the teeth, which are in a uniform series; but differs in the form of the teeth, which resemble those of the Dinosaurian *Acanthopholis*.

Family Pariotichidæ.—This family, although agreeing with the *Pariasauridæ* in the sculptured cranial bones and the roofing over of the quadratic region, differs in the dentition being of a carnivorous type. All the known genera are from the reputed Permian of North America; and the family is included by Professor Cope in the next suborder. The three genera are *Pariotichus*, *Ectocynodon*, and *Pantylus*. In *Ectocynodon* the first premaxillary tooth is tusk-like, and there is also an enlarged tooth in the middle of the maxil-

lary series. The nostrils are large and lateral; and at the junction of one of the bones of the palate with the maxilla, the tooth-bearing surface is wide, and supports four parallel rows of small obtuse teeth. In *Pantylus*, which was originally described as a Labyrinthodont, the teeth are more equal in size.

Suborder 2. Theriodontia.—This suborder, which is taken (after Dr Baur) to include the Pelycosauria of Professor Cope, is characterised by the absence of a bony roof over the quadratic region of the skull, and the presence of only a single wide temporal arch (fig. 979), apparently consisting of a conjoint squamoso-maxillary and quadrato-maxillary arcade. The mandible has no lateral vacuity.

In some cases, as in the American forms, the vertebræ are still notochordal; intercentra may be developed, to which the capitular heads of the ribs are articulated, and there are not more than two or three sacral vertebræ. The dentition is fully developed. In the palate of the African forms at least the maxillæ develop palatal plates to floor the nasal passage, and thus produce tall and nearly vertical posterior nares, strikingly like those of Mammals. The premaxillæ remain separate.

In those of the typical African forms in which the pelvis is known, the ilium is somewhat intermediate between that of the Pariasauria and Dicynodontia, having a distinct but small obturator foramen. The humerus is usually more or less of a Dicynodont type, having expanded extremities, and the entepicondylar foramen with its lower aperture opening on the palmar aspect of the bone (fig. 982); there is generally a marked thin flange on the postaxial border opposite this foramen which does not occur in the Dicynodonts.

Although evidently nearly related to the Pariasauria the present group departs farther from the Labyrinthodont type, as is shown by the loss of the roofing bones in the quadratic region, as well as of the superior temporal arcade, and by the absence of sculpture or mucous canals on the skull. This advance is also indicated by the development of secondary posterior nares, by the fuller attachment of the ilia to the sacrum, and the relatively larger centra of the vertebræ of the higher types; as well as by the development of the obturator foramen in the pelvis.

Family Tapinocephalidæ.—This family may be taken to include two gigantic Anomodonts from the Karoo system of the Cape, described under the names of *Tapinocephalus* and *Titanosuchus*. The former is known typically by the extremity of the cranium; the vertebræ probably belonging to it having short and notochordal centra. A pelvis, found in association with some limb bones, has been described under the name of *Phocosaurus*, but there is no

evidence to show that it does not belong to *Tapinocephalus*. These associated bones show that the coracoid was distinct from the precoracoid, and that the short and massive humerus had no ectepicondylar foramen. In *Titanosuchus* the dentition (as was probably the case with *Tapinocephalus*) was of a carnivorous type; the humerus is characterised by the presence of an ectepicondylar foramen (in addition to the entepicondylar), which pierced right through the shaft of the bone; while a bone incorrectly described as the pubis shows that the precoracoid was fused with the coracoid.

Family Galesauridæ.—Nearly the whole of the typical Theriodontia of Sir R. Owen may be provisionally included in this family, since, although some genera have single and others double nares, the skulls of the two types so closely resemble one another as apparently to render it impossible to refer them to distinct families. The family is characterised by the humerus (when known) being of a more elongated type than in the preceding family, and by the smaller size of its members; while the vertebræ were probably different from those of the latter, and had no intercentra. The dentition is of a carnivorous type, and differentiated into an anterior, or incisive, series separated by one large tusk or canine-like tooth, from a lateral series of cheek (or molar) teeth; thus simulating the dentition of carnivorous Mammals, and more especially that of the polyprotodont Mesozoic Marsupials. There are no teeth on the palate. The majority of the genera are from the Stormberg and Beaufort beds of the Karoo system of South Africa; and we are mainly indebted for our knowledge of the group to the labours of Sir R. Owen.

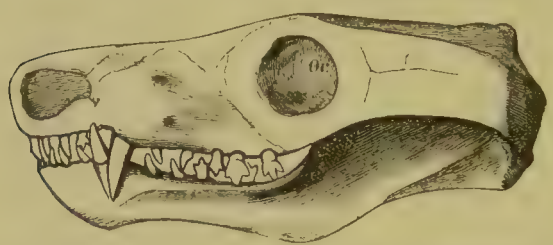


Fig. 979.—Left lateral aspect of the skull of *Galesaurus planiceps*; from the Karoo system of South Africa. Reduced. *Or*, Orbit. Only some of the cheek-teeth are shown.

In the type genus *Galesaurus*, with which *Nythosaurus* is identical, the skull (fig. 979) is much depressed, with the nares divided by a narrow septum; there are 4 anterior and 12 cheek-teeth, the latter having tricuspid crowns. In *Lycosaurus* (fig. 980, A, C) we have larger forms distinguished by the lateral compression of the skull, the distinctly double nares, short mandibular symphysis, and by the number of the cheek-teeth being reduced to 5; the development of the tusks being very great. *Ælurosaurus*, again, appears to be a nearly allied but still more specialised genus, in which, by the reduction of the septum, the nares have united to form a single

opening. *Cynodraco* (fig. 980, B) also includes large forms with greatly developed tusks, having compressed crowns with serrated edges like those of the Mammalian genus *Machærodus;* the nares being divided. Other genera from the Karoo system showing the latter feature are *Cynochampsa*, *Cynosuchus*, and *Scaloposaurus;* the latter being one of the smallest known forms. *Tigrisuchus*, again, is distinguished by its single nares; while *Gorgonops*, of the same deposits, has a narrow flattened skull, with the arrangement of the nares different from that obtaining in all the preceding genera, and

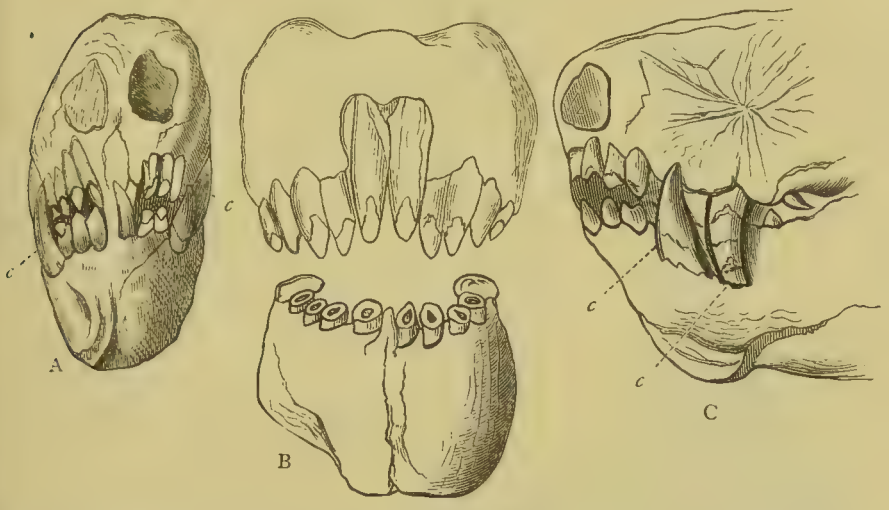


Fig. 980.—A, C, Anterior and lateral views of the skull of *Lycosaurus;* B, Anterior view of the skull of *Cynodraco;* from the Karoo system of South Africa. Reduced. *c* indicates the tusk-like (canine) teeth. (After Owen.)

may indicate a distinct family. *Deuterosaurus* and other forms from the Permian of Russia, which are included by Sir R. Owen in the typical Theriodontia, are noticed below.

Family Clepsydropidæ.—This name is applied by Professor Cope to carnivorous Theriodontia, distinguished from the *Galesauridæ* either by the development of teeth on the palate, or by the extraordinary character of their dorsal vertebræ, in which large intercentra are typically present. All the genera are typically from the reputed Permian deposits of North America. In the type genus *Clepsydrops* the premaxillary and maxillary teeth are of unequal size, and the dentary bone of the mandible has two enlarged tusks near its extremity. Teeth are also borne on the pterygoids; and the neural spines of the dorsal vertebræ are not excessively elongated. In *Dimetrodon*, the most remarkable character is the extraordinary development of the neural spines of the dorsal vertebræ, which resembled those of *Naosaurus* (fig. 981),

with the exception of having no horizontal processes. The height of the spine in one species is more than twenty times the length of the centrum; and Professor Cope concludes that these spines formed a kind of elevated fin on the back, of which it is difficult to imagine the use. *Naosaurus* differs from the preceding by the above-mentioned horizontal processes on the spines of the vertebræ (fig. 981). The premaxilla had one tusk; and there were two similarly enlarged teeth near the anterior extremity of the maxilla, behind which comes a series of some twelve teeth of equal size, with compressed and slightly recurved crowns. Numerous small obtuse teeth are also dotted over the palatines and pterygoids. This genus has also been recorded from the Permian of Bohemia. Other American genera included in this family by its founder are *Embolophorus*, *Edaphosaurus*, *Archæobelus*, *Theropleura*, and perhaps *Lysorophus* — *Theropleura* being characterised by the presence of well-developed abdominal ribs.

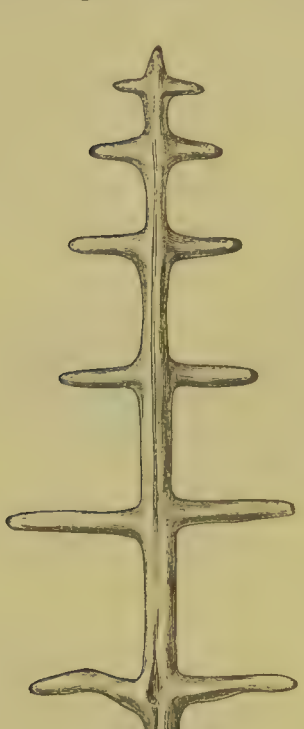


Fig. 981.—Anterior view of dorsal vertebra of *Naosaurus claviger*; from the Permian of Texas. One-sixth natural size. *Ce*, Centrum. (After Cope.)

Here may be mentioned the genus *Stereorhachis*, from the Lower Permian of France, of which the lateral cheek-dentition presents a considerable resemblance to that of *Naosaurus*, although it is not known whether teeth were present on the palate. The neural spines of the vertebræ are of normal type; but it is not known whether intercentra were present, or whether the centra were notochordal. The humerus (fig. 982) differs from that of the *Galesauridæ* in the contour of the distal extremity. Professor Seeley regards the above-mentioned humerus from the Karoo system of the Cape, described by him under the name of *Propappus*, as indicating an allied form, but there is nothing to justify this association. *Stereorhachis* may constitute the type of a distinct family, but there is at present no evidence to support the view that this genus (together with *Propappus*) represents a distinct order, for which the name Gennetotheria has been proposed.

Family Bolosauridæ.—This family is also typically known from the reputed Permian of North America, where it is represented by the genera *Bolosaurus* and *Chilonyx*. In the former, the teeth are fixed in shallow alveoli, and have their crowns ex-

panded transversely to the axis of the jaws. These crowns are swollen at their base, and have a low apex vertically divided into two portions, of which the inner one in the upper jaw is low and horizontal, and the outer forms a curved claw-like cusp — the anterior teeth consisting simply of an inner ledge and the outer cusp, and there being no enlarged tusks. *Metarmosaurus*, of the same deposits, may perhaps be referable to this family.

In the large *Deuterosaurus*, from the Russian Permian, the premaxillary teeth (fig. 983) approximate to the description of those of *Bolosaurus*, but there are large tusk-like teeth resembling those of the *Galesauridæ* behind the five premaxillary teeth; the nares being divided. This genus may be regarded as representing a distinct carnivorous family. A tooth from the Karoo system of South Africa, having the general characters of the anterior teeth of *Deuterosaurus*, but with the lateral borders of the inner surface of the crown forming ridges, has been made the type of the genus *Glaridodon*. An associated series of bones in the British Museum may belong to the same form; the vertebræ are notochordal, and the humerus agrees in size with the one mentioned below as *Brithopus*. Here may be noticed the genus *Rhopalodon*, from the Permian of Russia, founded upon a mandibular ramus which may belong to the same family. Perhaps, however, the most remarkable specimen from these deposits is the distal portion of a large humerus described under the name *Brithopus* (*Eurosaurus*); the proximal end of another humerus, which has received the name of *Orthopus*, probably belonging to the same species. The former specimen is remarkable for having both ectepicondylar and entepicondylar foramina—a condition elsewhere known only in *Titanosuchus* and *Sphenodon*. Dr Baur has suggested that this specimen may belong to a Rhynchocephalian, but it is certain that it is referable, as Sir R. Owen first pointed out, to the present suborder; and it is quite likely that it may prove to belong to *Deuterosaurus*, in which case this name should be superseded.



Fig. 982.—Anterior aspect of the imperfect left humerus of *Stereorhachis dominans*; from the Lower Permian of France. One-half natural size. (After Gaudry.)

Family Diadectidæ.—This family is also founded upon genera

from the Permian of North America, and includes *Diadectes*, *Empedias* (*Empedocles*), and *Helodectes*. The teeth (fig. 984) are transversely elongated like those of *Bolosaurus*, and are also divided by a median vertical ridge; but both the inner and the outer moieties are equally low. Their alveoli are not separated, and the edges of the crowns are obtuse, with tuberosities on some of them distinct from the apex of the main ridge. Professor Cope regards this peculiar type of dentition as indicative of a herbivorous diet. The brain-case differs from that of the *Clepsydropidæ* in a manner analogous to that in which the brain-case of the *Varanidæ*



Fig. 983.—Lateral view of a premaxillary tooth of *Deuterosaurus biarmicus*; from the Upper Permian of Russia. Half natural size.



Fig. 984.—Lateral and palatal view of a posterior tooth of *Empedias molaris*; from the Permian of North America.

is distinguished from the same part in other Lacertilia—that is, it is continued between the orbits so as to enclose the olfactory lobes in bone. *Phanerosaurus*, from the Permian of Germany, is referred by Professor Cope, from the structure of its vertebræ, to this or the preceding family.

Suborder 3. Dicynodontia.—In this suborder the vertebræ have no notochordal canal; intercentra are wanting; and the sacrum includes from four to five vertebræ. There is in no case more than one pair of teeth in the alveolar borders of the upper jaw, while there are none in those of the mandible. The palate is of the general type of that of the Theriodonts, but the premaxillæ unite to form a single beak-like bone, and the mandibular symphysis, which is very deep and laterally compressed, is likewise anchylosed. The nares are double; and it is probable that in some forms a part or the whole of the alveolar borders of the mandible was sheathed in horn; while the mandibular rami have lateral vacuities (fig. 985, B). There is a single temporal arcade, which appears to be a squamoso-maxillary one. In the pelvis the ilium is much expanded in an antero-posterior direction, the expanded plate

lying nearly parallel to the sacrum; and there is a small obturator foramen. The humerus (fig. 978) is expanded at the two extremities, with a prominent deltopectoral crest,[1] and with the lower aperture of the entepicondylar foramen opening on to the palmar aspect. The members of this group are found in the Stormberg and Beaufort beds of the Karoo system of South Africa, and the equivalent Gondwanas of Central India.

Family Dicynodontidæ.—This family is characterised by the absence of teeth on the palate. The type genus *Dicynodon* was the first known representative of the order, and was originally described by Sir R. Owen from specimens brought from South

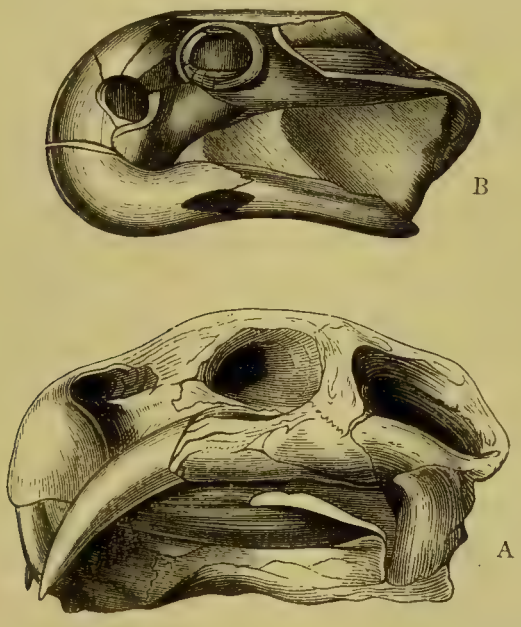


Fig. 985.—Lateral view of the skull of (A) *Dicynodon lacerticeps*, and (B) *Udenodon Baini*; from the Karoo system of South Africa. Reduced. (After Owen.)

Africa. It is characterised by the presence of a tusk-like tooth (fig. 985, A) growing from a persistent pulp in each maxilla—the rest of the jaws being edentulous, with trenchant edges. The profile of the skull is rounded, the maxillæ are not strongly ridged, the nares are approximated to the muzzle, and the supraoccipital forms a broad bar above the foramen magnum. This genus may also occur in the Panchet stage of the Indian Gondwanas. In *D. tigriceps* the skull has a length of 20 inches. In *Ptychosiagum*[2]

[1] The deltopectoral crest is the ridge on the right side of the upper half of the figure.

[2] This new name is proposed in lieu of *Ptychognathus*, which is preoccupied.

(*Ptychognathus*) there is also a pair of tusk-like upper teeth, but the skull is angulated, with strong ridges on the maxilla, the nares far behind the muzzle, and only a very narrow supraoccipital bar above the foramen magnum. The typical species are from South Africa, but another representative of the genus occurs in the Gondwanas of Central India, which was originally described as *Dicynodon orientalis*. A very imperfect and flattened skeleton from the Karoo system has been made the type of the genus *Cirognathus*, which is said to be characterised by the small size of the canine-like tooth, and the presence of only two phalangeals in all the digits except the third. It appears, however, that these alleged differences do not really exist, the difference in the humerus being due to a comparison of opposite aspects, and the number of phalangeals being apparently normal, so that this form probably belongs to *Dicynodon*. The same remark will apply to part of a skeleton from the same beds upon which the genus *Eurycarpus* has been founded. The genus *Udenodon* (*Oudenodon*) is characterised by the total absence of teeth (fig. 985, B), but is otherwise so closely allied to *Dicynodon* that it must certainly be included in the same family. The nares are somewhat approximated to the orbits, and the profile of the muzzle is rounded. It occurs in the Karoo system of the Cape Colony; and some of its representatives attained very large dimensions. *Cistecephalus* (*Kistecephalus*) comprises smaller forms from the same beds, in which the skull is much depressed, with the orbits directed frontally. There was a pair of tusks in the maxillæ.

The name *Platypodosaurus* has been applied to a considerable portion of the skeleton of a Dicynodont, from the Karoo system, of which the skull is unfortunately unknown, and which may prove to be identical with *Udenodon*, unless it belong to *Endothiodon*. The remarkably Mammalian structure of the pelvis, in which there is a small obturator foramen between the pubis and the ischium, is fully noticed in Sir R. Owen's description of the specimens.

Family Endothiodontidæ.—The remarkable genus *Endothiodon*, comprising large reptiles from the Karoo system of the Cape, forms the type of a family distinguished from the preceding by the presence of teeth on the palate. The skull presents a strong general resemblance to that of *Udenodon*, but the muzzle is more elongated, and the nares are terminal and overhung by the massive nasals. The alveolar borders of the jaws are trenchant, but the oral surface of the palate and mandible carry one or more longitudinal rows of columnar and cylindrical teeth. The remarkably Mammalian type of the palate of *Endothiodon* is noteworthy. The skull from the same deposits described as *Theriognathus* seems to belong to *Endothiodon*.

Endothiodon has been compared to the Rhynchocephalian *Rhynchosauridæ* and also to *Placodus;* but although there is a marked superficial resemblance between the three forms in the palate and teeth, yet this resemblance is but apparent, since while in *Endothiodon* the teeth are borne on a secondary bony floor beneath the narial passage, in the other genera they are supported on the proper surface of the palate, on which the posterior nares open directly, without the intervention of a secondary passage.

Suborder 4. Procolophonia.—According to a recent observer the genus *Procolophon*, represented by comparatively small forms from the Karoo system of the Cape, differs so decidedly from the Theriodontia that it is entitled to form a distinct suborder, showing marked signs of affinity with the Rhynchocephalia. The *Procolophonidæ* have a full dentition, but no tusk-like teeth, and the nares are double. Although the pectoral girdle still has a distinct precoracoid, yet its whole characters approximate to those of the Rhynchocephalian genus *Sphenodon.* The humerus also resembles the corresponding bone of the latter; and in the skull the pterygoids extend forwards in the same manner to join the vomers and exclude the palatines from the middle line; while there are no secondary posterior nares; and teeth are borne on both the pterygoids and vomers, as in the young of *Sphenodon.*

Group Placodontia.—Our sole knowledge of this group, represented by *Placodus* (fig. 986) and *Cyamodus* of the Middle Trias, or Muschelkalk of Germany, is derived from the skull, so that we are at present to a great extent in the dark as to their true affinities. These forms, after having been regarded as Ganoid Fishes, were referred by Sir R. Owen to the Sauropterygia; and the type genus resembles the Nothosaurs in the backward position of the nares and the form of the cranial rostrum. The skull has, indeed, been said to present many points of resemblance to that of the Anomodonts, and more especially *Endothiodon*, to which genus it is considered by Sir R. Owen to be closely allied. The resemblance in the form of the palate is, however, as already mentioned, only a superficial one; the present form having no floor to the narial passage, and the posterior nares opening directly into the roof of the mouth by horizontal apertures, as in the Sauropterygia. The skull is broad posteriorly, with double nares, a deep and apparently compound temporal

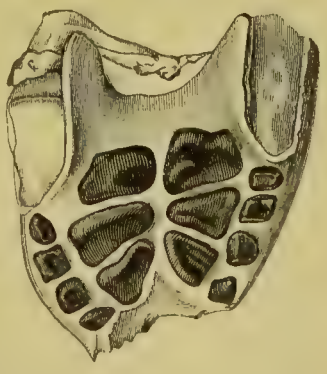


Fig. 986.—The imperfect palate of *Placodus gigas;* from the Muschelkalk of Bayreuth. One-fourth natural size. When entire the muzzle would form a produced rostrum.

arcade, and a postorbital bar. The palatal teeth (fig. 986) resemble paving-stones, and were probably adapted for crushing hard substances like the shells of Molluscs. In the upper jaw the teeth are arranged in an outer or maxillary series of small ones, and an inner or palatine series of larger ones; all being implanted in shallow sockets and replaced by vertical successors. In the mandible there is but one row of teeth. The number of palatal teeth varies in the different forms; and there are also modifications in the size and contour of these teeth, which aid in affording generic and specific characters. The premaxillary teeth may be of a more or less prehensile type. Till the vertebræ and limb-bones are known the position of these forms must remain uncertain; but it may be remarked that all the known limb-bones from the Muschelkalk, except those of Dinosauria, appear to be of a Sauropterygian type.

In the typical genus *Placodus* the skull is comparatively narrow, and has a long rostrum produced considerably in advance of the nares. The palatal teeth (fig. 986) have polygonal crowns, those of the palatine series being three in number on either side, and closely approximated; while the three premaxillary teeth are more or less chisel-like, and are separated by an interval from those on the palate. The mandible has a long symphysis, and two pairs of cutting-teeth. The maxillary teeth may be either four or five on either side. *Cyamodus* is readily distinguished by the great width and shortness of the cranium, which has no distinct rostrum, with the nares placed at the muzzle and the premaxillæ fused together. The palatal teeth have rounded crowns, the crown of the last palatine being very large; there may be either two palatine and three maxillary, or two maxillary and three palatine teeth. There were but two pairs of premaxillary teeth, which are not chisel-like. In the lower jaw the symphysis was triangular and comparatively short, and was probably devoid of teeth.

Recently Dr Gürich has proposed the name *Pleurodus* for an allied form from the Muschelkalk of Silesia, but since this term is preoccupied for a Crocodilian genus it will have to be changed.

Synaptosaurian Branch.—According to Dr Baur's scheme of classification this branch comprises the orders Sauropterygia and Chelonia; although Professor Cope and Mr Boulenger would also include the Rhynchocephalia. The typical Proganosauria of Dr Baur may be merged in the Sauropterygia. Although the Sauropterygia and Chelonia present many characters in common, yet it is not easy to give a definition of this branch. In all, however, the quadrate is firmly united to the skull; and all, or nearly all, of the dorsal ribs articulate with the vertebræ by single heads. As a general rule the palate is more or less completely closed, the pterygoids generally extending forwards to join the vomers. There may be

either one or two temporal arcades. A parietal foramen is present at least in the young. In all cases ossifications are developed upon the ventral aspect of the body, either in the form of abdominal ribs, or of a plastron; but there are none in the sclerotic of the eye. The sacral ribs are connected with the vertebræ by upper and lower articulations; and when chevrons are present they are mainly or exclusively attached to the hinder borders of the caudal centra. A precoracoid anchylosing to the scapula may be present in the pectoral girdle; and in the pelvis the pubis and ischium have expanded and flattened ventral surfaces, and the obturator foramen may be completed by the union of the ischium with the pubis of the same side. There is, moreover, a considerable structural resemblance between the limb-bones of the more generalised forms of the two orders, these bones always having terminal epiphyses; and the tarsus in both may be of a very primitive type. The humerus may have either an entepicondylar (ulnar) foramen and an ectepicondylar (radial) groove, or only the latter, or may be devoid of both. The ribs never have uncinate processes.

We are still very much in the dark as to the origin of these two orders, although the Sauropterygia can be traced back to a form presenting several Amphibian features, which appears to have been closely allied to the primitive Rhynchocephalians. From the disappearance of numerous segments in the vertebral column of the Chelonia during development, Professor Parker has suggested that this order has originated from a type allied to the Sauropterygia; and their plastron is almost certainly derived from, or developed upon, the abdominal ribs of a form allied either to the Rhynchocephalia or to *Mesosaurus*.

Order II. Sauropterygia.—In this extinct order the body was devoid of any exoskeleton, while the neck was more or less elongated, and the tail short. In the skull there is only the superior temporal arcade; the narial apertures are lateral and more or less approximated to the orbits; the premaxillæ are very large; and there is a well-developed parietal foramen in the adult. The prefrontal remains distinct; the postorbital may be separate from the postfrontal; typically there is a transverse bone; and the symphysis of the mandible is united by suture. The teeth, which are implanted in distinct sockets and confined to the margins of the jaws,[1] have curved sharp crowns, with fluted enamel. Each rib articulates to a single vertebra, and in the cervical region the costal facets, which may be either single or double, are situated entirely on the centrum, and generally are not prominent. The vertebræ are amphicœlous; and the neuro-central suture may be either persistent throughout

[1] Assuming that the Placodontia are distinct from this order.

life, or completely obliterated. All those vertebræ in which the costal articulation is on the centrum below the neuro-central suture may be reckoned as cervical; their number varying from about 21 to nearly 40. The centrum of the atlas is well developed, and there is a wedge-shaped intercentrum between the latter and the skull. The true cervicals are succeeded by a few vertebræ in which the costal articulation is partly on the arch and partly on the centrum, for which the name of pectorals has been proposed. The dorsal vertebræ have the costal articulation placed entirely on the arch, and generally forming an elongated transverse process. The caudal vertebræ are always furnished with true ribs, and also with chevron-bones, which may not be united below. The structure of the pectoral girdle is very remarkable, and has given rise to considerable diversity of opinion. In all forms the coracoids meet in a median symphysis, which may be short (fig. 987) or very long (fig. 988).

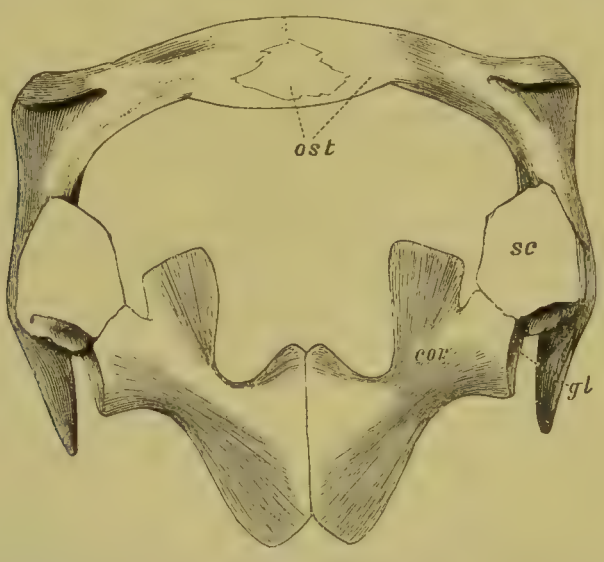


Fig. 987.—Ventral aspect of the pectoral girdle of *Nothosaurus mirabilis*; from the Muschelkalk of Würtemberg. Reduced. *ost*, Clavicle and interclavicles; *sc*, Scapula; *gl*, Glenoid cavity; *cor*, Coracoid.

In the generalised *Nothosaurus* (fig. 987) the scapula has only a small ventral portion, separated by a wide interval from that of its fellow. Anteriorly to these ventral plates of the scapulæ there is a slender arch consisting of a median and two lateral portions, corresponding to a similarly situated bone in *Plesiosaurus*. This arch is usually correlated with the interclavicle and clavicles; but from the deep-seated position of its representative in *Plesiosaurus*, Mr Hulke considers that in that genus it corresponds to the omosternum of the Amphibia, and if this interpre-

tation be correct, it will have the same homology in *Nothosaurus*.[1] As specialisation proceeds it appears that the scapulæ have tended to develop very large ventral plates, with a concomitant reduction and ultimate disappearance of the clavicular arch. The intermediate stage is shown in *Plesiosaurus* (fig. 997), where it will be seen that the ventral plates of the scapulæ are separated in the median line; and the culmination in *Cimoliosaurus*, where they unite in a median symphysis, and join the anterior extremities of the coracoids, while the interclavicle has disappeared. Mr Hulke regards the ventral plate of the scapula as representing the precoracoid of the Chelonia, but further evidence is required to prove this; the view that it represents the clavicle being obviously incorrect. In the pelvis the pubis usually forms a wide plate, while the ischium is somewhat chopper-shaped; in some cases the pubis and ischium of each side unite to enclose an obturator foramen. The ischia are strikingly like those of the Amphibia, and have a long symphysis. The limbs are subject to considerable variation; those of the earlier generalised forms being adapted for progression on land, while in the specialised types they are modified into paddles. In all cases, however, the limbs are readily distinguished from those of the Ichthyopterygia by the relatively longer humerus and femur, and the absence of interdigital bones. The limb-bones are regarded by Professor Seeley as showing signs of Amphibian affinity. A peculiar feature in the limb-bones is that the epiphyses (fig. 989) of the humerus and femur are enormously developed, and form large cones at either extremity of the bones, almost, or completely, meeting in the middle of the shaft, which is reduced to a pair of elongated cups. The bones of the palate

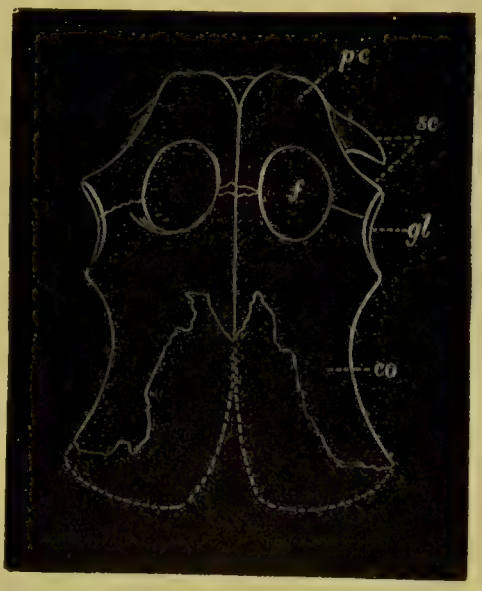


Fig. 988.—Ventral aspect of the pectoral girdle of *Cimoliosaurus* (*cf*) *trochanterius*; from the Kimeridge Clay. Reduced. *sc*, Scapula; *pc*, Ventral (precoracoidal) plate of do.; *gl*, Glenoid cavity; *f*, Scapular foramen; *co*, Coracoid. (After Hulke.)

[1] In the British Museum Catalogue of Fossil Reptilia Mr Hulke's interpretation of the homology of these bones was provisionally adopted, but the writer now considers that the other interpretation is probably the true one.

never develop plates to form a floor to the nasal passage, so that the posterior nares also open directly into the mouth by horizontal apertures (fig. 991).

This order ranges in time probably from the Permian and certainly from the Trias to the Upper Chalk, and we are enabled to trace the gradual evolution of the specialised marine forms from those less widely separated from a normal type. All these reptiles appear to have been carnivorous.

Family Mesosauridæ—The genus *Mesosaurus*, originally described from the Karoo system of Griqualand in South Africa, which is probably of lower Mesozoic age, but subsequently found in beds of uncertain age in Brazil, and described under the name of *Stereosternum*, includes small reptiles regarded by Dr Baur as

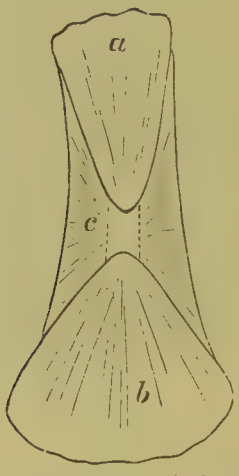


Fig. 989.—Longitudinal section of a Sauropterygian humerus; from the Kimeridge Clay; one-sixth natural size. *a*, Proximal, *b*, Distal epiphysis; *c*, Shaft.

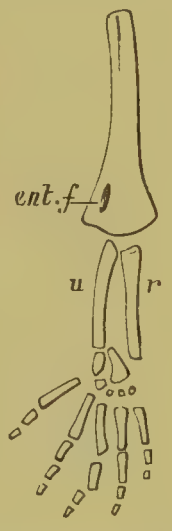


Fig. 990.—Ventral aspect of the left pectoral limb of *Mesosaurus tenuidens;* from the Karoo system of Griqualand. *ent.f*, Entepicondylar foramen of humerus; *r*, Radius; *u*, Ulna.

constituting a distinct order — the Proganosauria, — but which appear to be so closely related to the *Nothosauridæ*, that there can be little, if any, hesitation in including them in the same order. The Brazilian form was originally referred with some hesitation by Professor Cope to the Amphibia. One of the most peculiar features of this genus, in which it differs from all other groups except the Amphibia, the extinct *Palæohatteria*,[1] and perhaps the Chelonia is the separation of the fourth and fifth tarsalia, so that each metatarsal articulates with a distinct tarsale. The centra of the vertebræ

[1] See Rhynchocephalia, *infra*.

have a small notochordal canal, and are small in comparison to the neural arches; while the ribs seem to have been anchylosed to the vertebræ, and were of great thickness, like those of the next family. The system of abdominal ribs was strongly developed. The skull is much elongated, and has slender recurved teeth, which were in all probability implanted in distinct alveoli. The pectoral girdle appears to be very similar to that of the *Nothosauridæ*, the presumed interclavicle not being T-shaped; and a similar close resemblance is presented by the pectoral limb (fig. 990), in which the humerus has an entepicondylar, or ulnar, foramen, like that of Mammals. The pelvis is considered to have had only a very small obturator foramen; the ischia and pubes forming broad expanded plates like those of Amphibia and other Sauropterygia. The terminal digits were devoid of claws; and the feet were probably webbed like those of frogs.

Dr Baur makes this genus the type of the order Proganosauria, in which he would also include the undermentioned genus *Palæohatteria;* and regards this order as the connecting-link between Amphibians and Reptiles. Although there is something to be said in favour of this view, yet the manifest affinity of *Mesosaurus* to the more typical Sauropterygia, and of *Palæohatteria* to the Rhyncho-

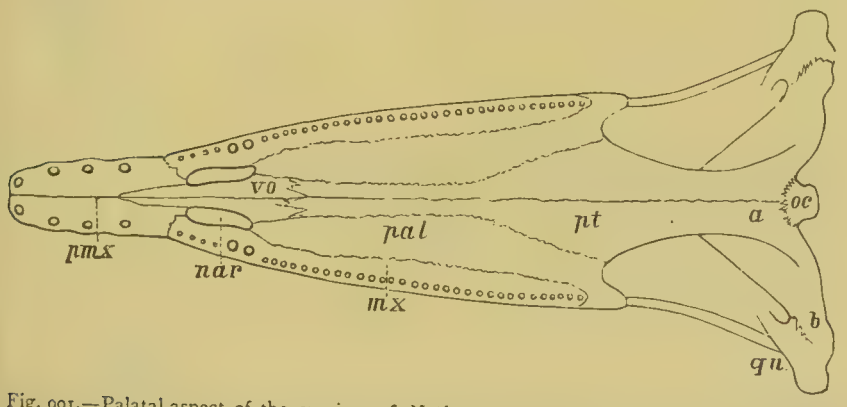


Fig. 991.—Palatal aspect of the cranium of *Nothosaurus mirabilis;* from the Muschelkalk. One-eighth natural size. *pmx*, Premaxilla; *nar*, Posterior nares; *vo*, Vomer; *mx*, Maxilla; *pal*, Palatine; *pt*, Pterygoid; *a*, Ala of do.; *b*, Quadratic ridge of same; *qu*, Quadrate; *oc*, Occipital condyle. The posterior extremity of *pal* is probably formed by a distinct transverse bone.

cephalia, seem to render it more advisable to refer those genera to the two orders in question, of which they will respectively form the most generalised stage. By this arrangement the intimate connection of both orders with the Amphibia will be made manifest.

Family Nothosauridæ.—In this family, which comprises some forms of large size, the limbs were furnished with claws, and adapted to a certain extent for walking. In the skull the pterygoids either

diverged posteriorly, or gave off wings uniting in the middle line upon the basi- and presphenoid, and thus completely closing the posterior portion of the palate (fig. 991)—an approximation to the latter arrangement occurring in some Chelonia. The palate was also devoid of infraorbital vacuities. The coracoids (fig. 987) had a short median symphysis, not extending as far forwards as the scapular articulation, and also had a groove; while the ventral plates of the scapulæ were very small. Typically, the cervical vertebræ have double costal facets, while the transverse processes of the dorsals are very short, and remarkable for the vertical elongation of their articular faces. The humerus and femur are elongated —the former (fig. 993) having an entepicondylar foramen, but no distinct distal expansion. The ischium and pubis did not unite to enclose an obturator foramen.

The known forms occur typically in the Muschelkalk, or Middle Trias, of the Continent, but some of them range up into the overlying Keuper, and one species is found in the Bunter, or Lower Trias. In the typical genus *Nothosaurus* the skull (figs. 991, 992) is long and much depressed, the length of the post-orbital exceeding that of the preorbital portion. The characters

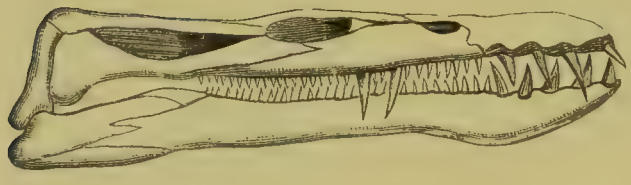


Fig. 992.—Right lateral aspect of the skull of *Nothosaurus mirabilis*. Reduced. (After Meyer.)



Fig. 993.—Ventral aspect of the right humerus of *Conchiosaurus*. One-half natural size. *Entf*, Entepicondylar foramen; *a*, Ectepicondylar groove.

of the palate are shown in fig. 991. *Conchiosaurus* is a closely allied but smaller form, in which the teeth are club-shaped. In *Simosaurus* the skull is characterised by the breadth of the facial portion and its stout teeth. The type species is nearly equal in dimensions to the larger species of *Nothosaurus*. Finally, *Pisto-*

saurus is distinguished by the posterior divergence of the pterygoids, and not improbably by the presence of long transverse processes to the dorsal vertebræ; both of these features being Plesiosaurian. The preorbital portion of the skull is very narrow. Although the members of this family have lost all traces of a notochordal canal in the centra of the vertebræ, yet the ossification of these centra has taken place in the same manner by means of a sheath investing the notochord.

Family Lariosauridæ.—This family is closely allied to the preceding, but the limbs approximate to those of the *Plesiosauridæ*. The skull, at least in one genus, has infraorbital vacuities on the palate, and the coracoid has no notch at its glenoidal extremity. The femur always remains an elongated bone, longer than the epipodials and metapodials collectively; but the humerus may be comparatively short, and is more or less expanded at its distal extremity; while in *Lariosaurus*, although not in the other forms, it has lost its foramen. The terminal phalangeals of the pes still retain their claws. In *Neusticosaurus* it is thought that cervical ribs were wanting. The type genus *Lariosaurus* comprises one medium-sized species from the Trias of Lombardy, and according to Dr Baur, has both limbs adapted for walking. The palate is unknown. In *Neusticosaurus*, from the Lettenkohle at the base of the Keuper of Würtemberg, Professor Seeley considers that the pectoral limb had become modified into a paddle, although this conclusion is not accepted by Dr Baur. It appears probable that a small reptile, described from the Trias of Italy under the preoccupied name of *Pachypleura*, is not more than specifically separable from *Neusticosaurus*. The type species of the latter was about one foot in length, and was probably of amphibious habits.

It may be convenient to notice here two small Triassic reptiles which are referred by Dr Baur to this family, although Dr Deecke considers that at least the second has more affinity with the Lizards. These genera are *Dactylosaurus*, from the Muschelkalk of Silesia, and *Macromerosaurus*, from the Italian Trias; the former being almost certainly referable to this order, and perhaps not separable from *Neusticosaurus*. In this connection it should be observed that Dr Bassani considers *Macromerosaurus* to be identical with the type species of *Lariosaurus*, and that *Neusticosaurus* is not generically separable from the latter. *Pachypleura* is, however, regarded as distinct from *Neusticosaurus*, in which case it will require a new name, as the present one is preoccupied.

Finally, it should also be mentioned that some authorities would regard the two preceding families as constituting a distinct sub-order—the Nothosauria—but the transition to the next family is almost complete.

Family Plesiosauridæ.—With this group we come to the consideration of the typical members of the order, all of which were adapted for a purely aquatic life, and probably frequented coasts and estuaries. In the skull the pterygoids diverge posteriorly, and do not overlie the basisphenoid; while there were small infraorbital vacuities in the palate. The dorsal vertebræ have long transverse processes. In the pectoral girdle the scapulæ have large ventral plates, which may meet in the middle line; and the symphysis of the coracoids is much elongated, and extends in advance of the scapular articulation. In the limbs (fig. 994) the humerus and femur were comparatively short and distally expanded; the former being devoid of a foramen. The bones of the second segment are likewise very short, and strangely altered from the normal form. In certain cases, moreover, a third bone (fig. 998) articulates with the humerus and femur, of which the homology will be discussed under the head of the Ichthyopterygia. The metacarpals and phalangeals are, however, still elongated, but the number of the latter is increased beyond the normal complement. Further, the terminal claws have disappeared; and the whole limbs were doubtless enveloped in a common integument, to form paddles after the fashion of the turtles. The coracoid (fig. 988) is remarkable for its great

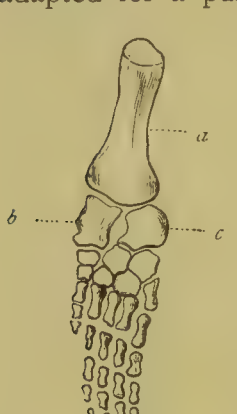


Fig. 994.—Dorsal aspect of the left pectoral limb of *Plesiosaurus Hawkinsi*; from the Lower Lias of Dorsetshire. Reduced. *a*, Humerus; *b*, Radius; *c*, Ulna.

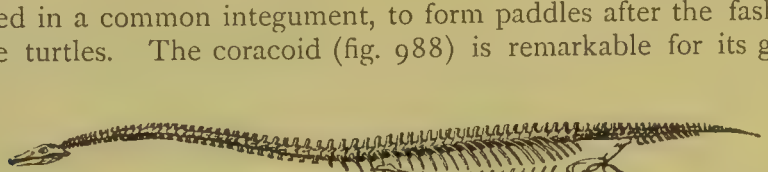


Fig. 995.—Skeleton of *Plesiosaurus dolichodirus*; from the Lower Lias. Greatly reduced. (After Conybeare.)

antero-posterior length, and has no fontanelle. This family includes some forms of huge dimensions; its range extending from the Rhætic, or Uppermost Trias, to the Chalk.

The *Plesiosauridæ*, like the Crocodiles of the present day, differ greatly among themselves in the relative length of the mandibular symphysis, as is shown in the accompanying woodcut. In the present family it appears, however, that the result of evolution and specialisation has been towards the gradual lengthening of this sym-

physis; whereas among the Crocodilia the tendency has been precisely in the opposite direction.

This family has been divided into a large number of genera, but since several of these are not really distinct it will suffice to adopt a smaller number of such divisions. The genus *Plesiosaurus*, as now restricted, is exclusively confined to the Upper Trias (Rhætic) and Lias. Owing to the beautiful preservation of many of the species

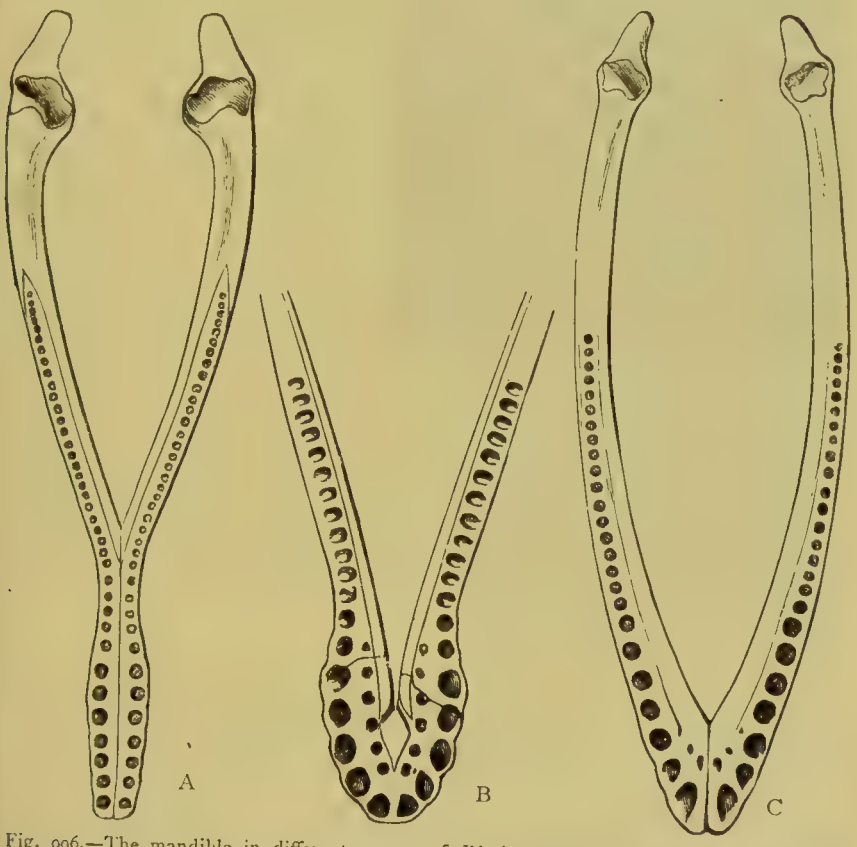


Fig. 996.—The mandible in different genera of *Plesiosauridæ*. Reduced. A, *Peloneustes philarchus*, from the Oxford Clay, one-eighth natural size; B, *Thaumatosaurus indicus*, from the Upper Jurassic of India, one-seventh natural size; C, *Plesiosaurus dolichodirus*, two-fifths natural size.

this genus has been long known to science; and its remains were admirably described in the first third of the present century by the late Mr Conybeare and Dean Buckland, who with remarkable foresight hinted at the affinity of these strange and weird forms of Reptilian life to the Chelonia. In this genus the skull is either small with a short mandibular symphysis (as in fig. 996, C), or moderately large with a longer symphysis and rostrum. The teeth are generally slender, without carinæ, and the terminal ones are not much larger

than the others in the more typical species. The neck is more or less elongated, with the anterior vertebræ in most cases very small. The cervical ribs and neural arches are firmly articulated to the centra of the vertebræ, but traces of the suture usually persist; in the cervical region the facets for the articulation of the ribs are usually double, and the terminal faces of the centra generally ellipsoidal, and more or less cupped. The most characteristic features of the genus are, however, to be found in the pectoral girdle (fig. 997), in which the scapulæ are relatively small, and widely separated in the middle line, where they rest upon the interclavicle, with its small and deep notch. The coracoids are, moreover, long and rather narrow, with a median production in advance of the glenoid cavity; while the foramen between the coracoid and scapula is very large and open towards the interclavicle.

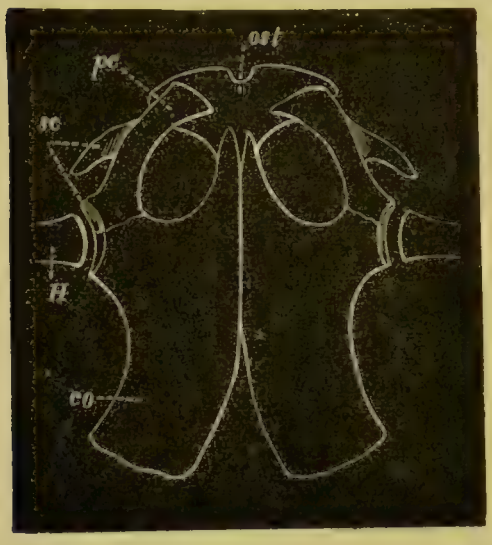


Fig. 997.—Ventral aspect of the pectoral girdle of *Plesiosaurus dolichodirus*; from the Lower Lias of Dorsetshire. Reduced. *ost*, Interclavicle; *sc*, Scapula; *pc*, Ventral plate of do.; *co*, Coracoid; *H*, Head of humerus. (After Hulke.)

This genus may be divided into three groups. The *Longirostrine* group, represented by *P. rostratus* of the Lower and *P. longirostris* of the Upper Lias, is characterised by the comparatively elongated mandibular symphysis, and the extremely short neural spines and single costal facets of the majority of the cervical vertebræ. In the typical group we have *P. dolichodirus* with its extremely long neck (fig. 995), the shorter-necked *P. Hawkinsi*, and the large *P. Conybeari*, all being from the Lower Lias. These forms have a moderately short mandibular symphysis (fig. 996, c), while the centra of the cervical vertebræ are never greatly elongated, and there are double costal facets and moderately tall neural spines in this part of the vertebral column. The third group is represented only by *P. homalospondylus*, of the Upper Lias, which is characterised by the great elongation of the centra of the cervical vertebræ, which have flat terminal faces, and enormously tall neural spines. The resemblance of these vertebræ to those of the cervicals of the typical group of the Jurassic and Cretaceous genus *Cimoliosaurus* suggests the origin of the latter group from the present; whereas on similar grounds it may be suggested that the *Cœlospondyline* group of *Cimoliosaurus* has originated from the typical group of *Plesiosaurus*. In all species of the present genus the radius and ulna (fig. 994) still retain evidence of their

original character as long bones, and are separated by a well-marked interval.

Another exclusively Liassic and perhaps Rhætic genus is *Eretmosaurus*, which had a long neck and probably a small head like *Plesiosaurus*, but with a very different type of pectoral girdle. Thus the coracoids had no median production in advance of the glenoid cavity; while the scapulæ were large, and articulated together in the median line, and posteriorly were united by their whole length with the coracoids, leaving only very minute coracoidal foramina. If an interclavicle were present it had become fused with the scapulæ. The type species is from the Lower Lias, but there is another in the Upper Lias. The largest genus of the family is, however, *Cimoliosaurus*, in which we may conveniently include those forms described under the names of *Discosaurus*, *Elasmosaurus*, *Mauisaurus*, *Polycotylus*, *Muræosaurus*, and *Colymbosaurus*. This genus was originally described upon the evidence of a very large species from the Cretaceous of New Jersey, with which *Discosaurus*, and probably *Elasmosaurus*, are specifically identical. The New Zealand Cretaceous species described as *Mauisaurus* is closely allied; and it has yet to be proved that the type species is even specifically distinct from the European *C. constrictus*. Many of the other species differ considerably from these typical forms, but if generic divisions are once made it seems impossible to know when to stop.



Fig. 998. — Ventral aspect of the right humerus, radius (*T*), ulna (*i*), and pisiform (*F*) of *Cimoliosaurus trochanterius*; from the Kimeridge Clay of Dorsetshire. Reduced. (After Hulke.)

The genus in the above extended series may be characterised as follows. The teeth and skull are relatively small, the mandibular symphysis is short, and the neck usually very long, with the anterior vertebræ relatively small. The vertebræ are more or less elongated, and generally have the neural arches and the cervical ribs completely anchylosed to the centra in the adult; the costal articulations always forming single facets in the cervical region. In the pectoral girdle (fig. 988) the scapulæ have very large and wide ventral plates, meeting in the middle line, without any trace of an interclavicle, and usually sending down a median process to join the coracoids, and thus com-

pletely closing the scapulo-coracoidal foramen.[1] The humerus (fig. 998) is usually longer than the femur; and both these elements may articulate distally with either two or three (figs. 998, 999, 1000) bones, which in the later instances lose all resemblance to the normal elongated form. The ischia are relatively short.

This genus may be divided into two groups, according to whether the vertebral centra have nearly flat or deeply cupped centra. In the former group we have the large *C. truncatus* of the Kimeridge, and the smaller *C. plicatus* (fig. 1000 *bis*) and *C. Richardsoni* (fig. 1000) of the Oxford Clay, in both of which the humerus articulates only with the radius and ulna; the latter species being distinguished by its shorter cervical vertebræ.



Fig. 999.—Ventral aspect of part of the right pelvic limb of *Cimoliosaurus portlandicus;* from the Portland Oolite. Reduced. *T*, Preaxial; *F*, Postaxial border; 66, Tibia; 67, Fibula; 67′, Homologue of the pisiform; *t*, Tibiale; *c* 1, Intermedium; *c* 2, Fibulare; *f*, Postaxial tarsal. (After Hulke.)

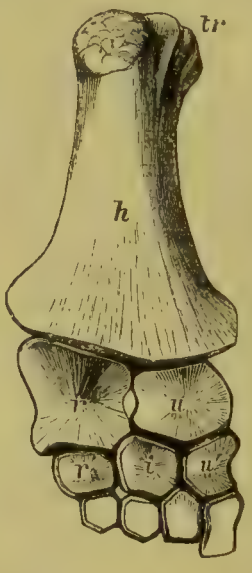
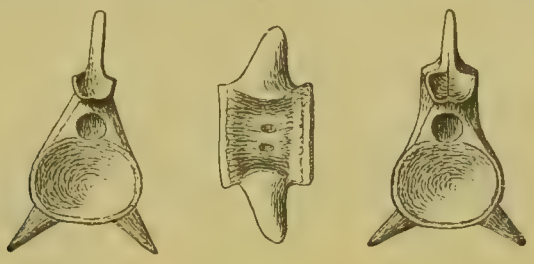


Fig. 1000.—Ventral aspect of part of the right pectoral limb of *Cimoliosaurus Richardsoni;* from the Oxford Clay. One-eighth natural size. *h*, Humerus; *tr*, Trochanter of do.; *r*, Radius; *u*, Ulna; *r'*, Radiale; *i*, Intermedium; *u'*, Ulnare. (After Mansel-Pleydell.)

In *C. portlandicus*, of the Portland Oolite and Purbeck, there were three short bones articulating with the humerus and femur (fig. 999). It is in the Cretaceous, however, that we meet with the largest representatives of this group, which comprise *C. constrictus*, of the European Gault and Chalk; *C. vetustus* and *C. platyurus*, of the Cretaceous of North America; and *C. Haasti*, in the corresponding strata of New Zealand. These were enormous reptiles, with an estimated length of between 30

[1] Occasionally, as in *C. durobrivensis*, of the Oxford Clay, this bar may be absent, but it is not known whether this is only an individual peculiarity.

and 40 feet, and having nearly 40 cervical vertebræ. In the second group, which apparently corresponds to the genus *Polycotylus* of Professor Cope, we have, in the Oxford Clay, *C. oxoniensis* and *C. eurymerus*, in which the humerus articulates with only the radius and ulna, and in



1 2 3

Fig. 1000 *bis*.—A cervical vertebra of *Cimoliosaurus plicatus*; from the Oxford Clay. One-fifth natural size. 1, Posterior; 2, Inferior; 3, Anterior aspect. (After Phillips.)

the Kimeridge the larger *C. trochanterius*, in which the pisiform also joins the humerus (fig. 998). The very small *C. valdensis*, of the Wealden, may have been of freshwater habits; while in the Chalk we find the larger *C. Bernhardi*. This group appears to have been also represented in the Cretaceous of North America and New Zealand. A species from the Cretaceous of Kansas, described under the name of *Trinacromeron*, has three bones articulating with the humerus.

The imperfectly known genus *Polyptychodon* (*Lutkesaurus*), of the Middle and Upper Cretaceous of Europe, appears to be allied to *Cimoliosaurus*, but with a relatively larger head and teeth, and probably with a much shorter neck. The teeth, which are very abundant in the Cambridge Greensand, have subconical crowns, with strongly-marked ridges, of which a considerable number generally stop short of the summit. These Reptiles must have attained huge dimensions. The genera we have now to consider indicate a different branch from that to which the two preceding genera belong. The first of these is *Thaumatosaurus* (in which *Rhomaleosaurus* may be included), typically occurring in the Great Oolite of Würtemberg, but extending downwards to the Lower Lias and upwards to the Kimeridge Clay of England. In these forms the skull and teeth were relatively large, the latter being often carinated, and the mandibular symphysis (fig. 996, B) comparatively short, with the first five or six teeth enlarged. The neck



Fig. 1001.—Dorsal aspect of part of the left pelvic limb of *Peloneustes philarchus*; from the Oxford Clay. One-sixth natural size. *fe*, Distal half of femur; *t*, Tibia; *f*, Fibula; *t'*, Tibiale; *i*, Intermedium; *f'*, Fibulare. The tibia is drawn rather too small in proportion to the fibula.

was short, and the cervical vertebræ have comparatively short and distinctly cupped subcylindrical centra, carrying double costal facets; while the arches and cervical ribs were firmly articulated to the centra. In the pectoral girdle the scapulæ and coracoids were of the general type of those of *Plesiosaurus;* but the clavicular

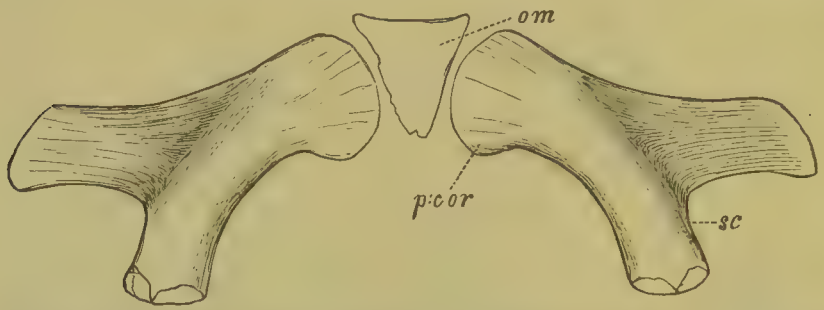


Fig. 1002.—Anterior part of the pectoral girdle of *Peloneustes philarchus;* from the Oxford Clay. Reduced. *om*, Interclavicle; *sc*, Scapula; *p.cor*, Ventral plate of do. The ventral aspect is shown.

arch was greatly elongated transversely, and was probably overlapped by the scapulæ. The humerus was longer or shorter than the femur, and articulated only with the radius and ulna, which were considerably elongated, and separated by a distinct interval. This genus is represented in the Lower Lias by *T. megacephalus* and *T. arcuatus*, and in the Upper Lias by the gigantic *T. Cramptoni*, which attained a length of some twenty feet. The type species, only known by detached teeth and vertebræ, occurs in the Great Oolite of the Continent; while *T. indicus* (fig. 996, B) is found in the Upper Jurassic of India.

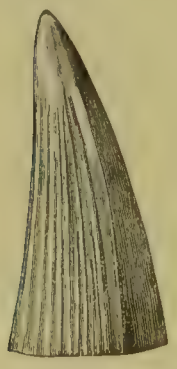


Fig. 1003.—Crown of a tooth of *Pliosaurus brachydirus;* from the Kimeridge Clay of Ely. One-half natural size.

In the genus *Peloneustes*, of the Oxford and Kimeridge Clays, the coracoids (fig. 1001) do not appear to have been produced anteriorly in the middle line; while the scapulæ have their ventral surface broad and flat, and the dorsal surface reduced (fig. 1002). The same figure also shows the extremely small size of the interclavicle. The ischia were very long. The mandibular symphysis (fig. 996, C) is greatly elongated; but the vertebræ agree with those of *Thaumatosaurus* in the firm attachment of the arches and cervical ribs to the centra, although the centra themselves have the terminal faces flatter, and with a transversely elliptical and somewhat angulated contour. The radius and ulna are nearly as broad as long, and have only a very small interval between them. The most specialised genus of this branch is *Pliosaurus* (*Ischyrodon*, *Spondylosaurus* or *Lio-*

pleurodon), which thus occupies a somewhat similar position to the one held by *Polyptychodon* in the preceding branch. This genus is represented by several species of gigantic Reptiles ranging from the Oxford to the Kimeridge Clay, but of which derived remains are also found in the Lower Greensand of Potton, in Bedfordshire. The skull and teeth (fig. 1003) are relatively very large; the former having a somewhat shorter mandibular symphysis than in *Peloneustes*. The teeth are carinated, and in the Kimeridgian species the space between the two carinæ is nearly flat, and

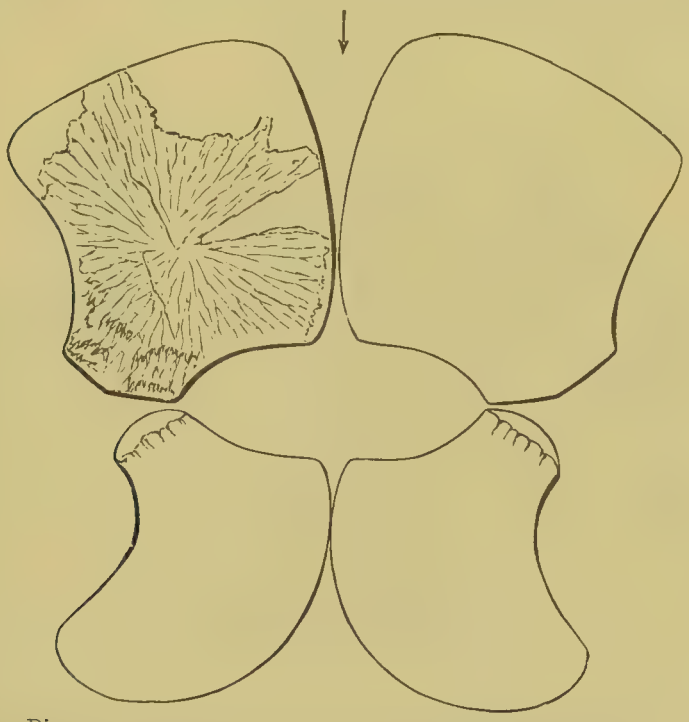


Fig. 1004.—Diagram of the ventral aspect of the pelvic girdle of a young Pliosaur. The upper bones are the pubes, and the lower the ischia. In the adult the ischia become more elongated, and their inner borders should have been placed more nearly parallel. (After Phillips.)

devoid of ridges. The neck is very short, and all the cervical vertebræ (fig. 1005) are relatively large, with nearly flat terminal faces to the very short centra, which in the anterior region have two distinct and often very prominent costal facets. A peculiar feature of all the vertebræ is, that the arches were only articulated to the centra by cartilage, so that they are always found detached. The pectoral girdle was of the general type of that of *Peloneustes*, but it is not improbable that the interclavicle was absent. The humerus was shorter than the femur, and the radius and ulna in the Kimeridgian forms have become much

shorter than in that genus, and have scarcely any intervening space, but in one of the species from the Oxford Clay they have the same form as in the latter. The general arrangement of the ventral bones of the pelvis is shown in the woodcut. In the huge *P. macromerus*, of the Kimeridge Clay, the length of the lower jaw was nearly six feet, and that of the femur one yard, by which some estimate can be formed of the gigantic dimensions attained by the entire animal. Pliosaurs were widely distributed over Europe, and have been described from England, Germany (as *Ischyrodon*), France (as *Liopleurodon*), and Russia (as *Spondylosaurus*). No remains of this genus have, however, been hitherto

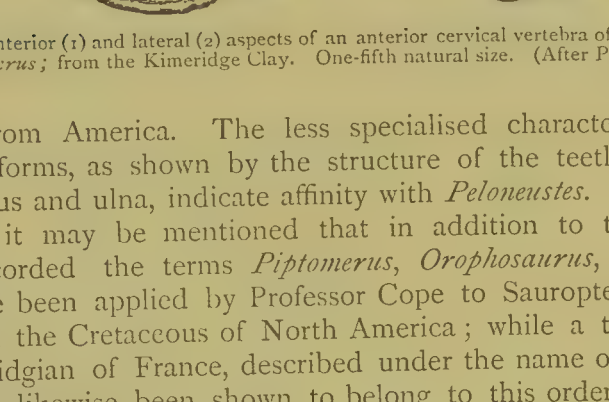


Fig. 1005.—Anterior (1) and lateral (2) aspects of an anterior cervical vertebra of *Pliosaurus macromerus*; from the Kimeridge Clay. One-fifth natural size. (After Phillips.)

recorded from America. The less specialised characters of the Oxfordian forms, as shown by the structure of the teeth, and the longer radius and ulna, indicate affinity with *Peloneustes*.

Finally, it may be mentioned that in addition to the names already recorded the terms *Piptomerus*, *Orophosaurus*, and *Uronautes* have been applied by Professor Cope to Sauropterygian remains from the Cretaceous of North America; while a tooth from the Kimeridgian of France, described under the name of *Hæmatosaurus*, has likewise been shown to belong to this order, although originally regarded as Crocodilian.

Order III. Chelonia.—With the Tortoises, Turtles, and their allies, we enter upon the consideration of the first of the existing orders of Reptiles. In this order the cervical and dorsal vertebræ are not numerous; the body is short and wide, and has a more or less complete bony shell, of which the ventral part, or plastron, consists of few elements of dermal origin, while the dorsal, or carapace, may be in great part of endoskeletal origin. There is generally a horny epidermal exoskeleton. The skull may occasionally have two temporal arcades, but more generally only the lower one is present (fig. 1007), and in some cases even that may be absent. The nares (fig. 1024) are single and terminal; the premaxillæ very small; and there is no parietal foramen in the adult; but there is a distinct

opisthotic bone (fig. 1024). The dentary bones of the mandible are generally fused together; the postorbital is welded with the postfrontal, and usually the prefrontal with the nasal; while the supraoccipital is prolonged backwards. There is no transverse bone. The palate is completely closed by the junction of the pterygoids with the basisphenoid, and often with one another (fig. 1017 *bis*). In all existing forms teeth are absent, and the trenchant jaws ensheathed in horn. Each rib articulates at the junction of two vertebræ; there are

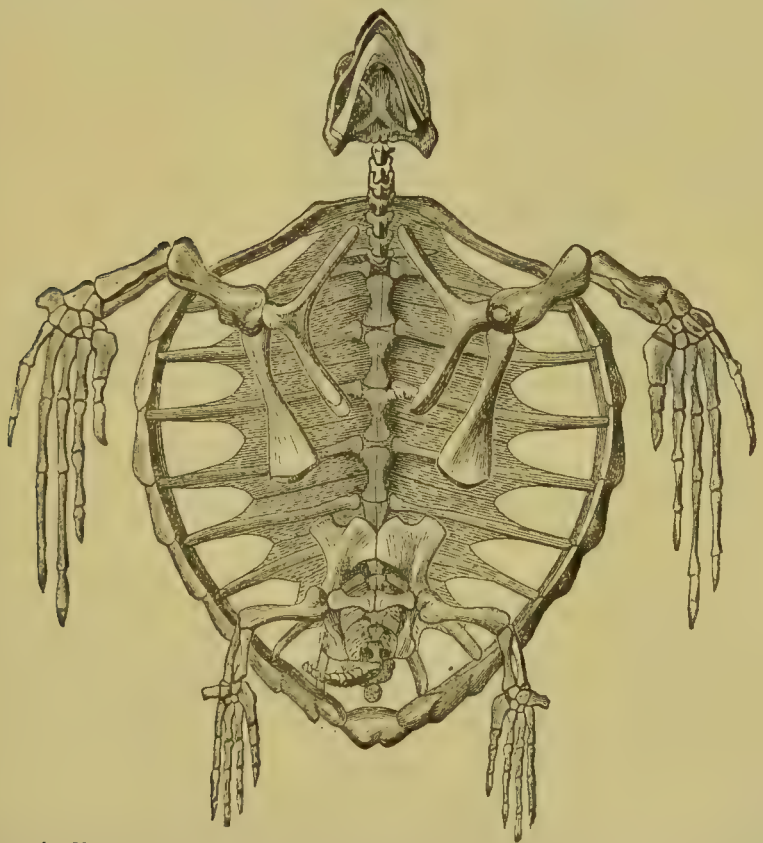


Fig. 1006.—Ventral aspect of the skeleton of a young Loggerhead Turtle (*Thalassochelys caretta*), with the plastron removed. Much reduced. The coracoid and precoracoid of opposite sides are here represented as widely separated from one another. (After Owen.)

no ribs in the cervical region, and no transverse processes to the dorsal vertebræ. The vertebræ may have procœlous, opisthocœlous, or amphicœlous centra in different parts of the column of the same individual. In the pectoral girdle (fig. 1008), which is situated within the ribs, the coracoid is the widest of the three cartilage bones; and the coracoid and precoracoid of opposite sides are respectively connected in the middle line by ligamentous tissue only. The connection between the scapula and precoracoid is short, and there is

no trace of a sternum. In the plastron (fig. 1009), developed on the ventral aspect, the *epiplastrals* (*es*) and *entoplastral* (*s*) correspond to the three plates of the Labyrinthodont thoracic buckler,

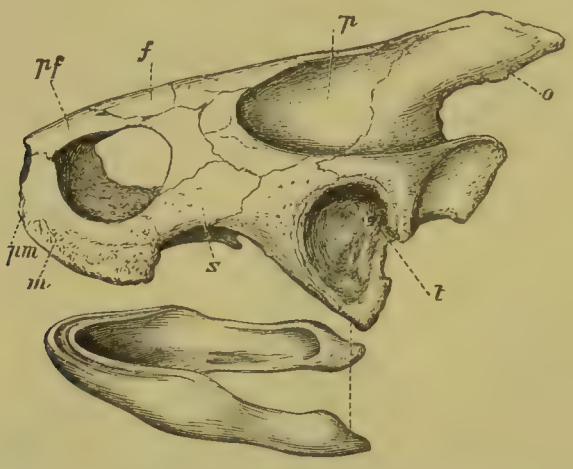


Fig. 1007.—Left lateral aspect of the skull of *Testudo*. *pm*, Premaxilla; *m*, Maxilla; *pf*, Prefrontal and nasal; *f*, Frontal; *p*, Parietal; *o*, Supraoccipital; *z*, Jugal, behind which is the quadratojugal, and above the postfrontal; *t*, Quadrate, showing the incompleteness of the tympanic ring posteriorly; the bone above this ring is the squamosal.

and apparently represent the clavicles and interclavicle. There are in addition paired *hyo-*, *hypo-*, and *xiphiplastrals;* and in some forms (fig. 1012) there are *mesoplastrals* intercalated between the hyo- and hypoplastrals. The pelvic, like the pectoral girdle, becomes in the adult placed on the inner side of the ribs, and has the pubis much larger than the ischium (fig. 1006). The two latter may be anchylosed to the xiphiplastral, and the obturator notch may be converted into a foramen. The humerus has an ectepicondylar groove, which is occasionally converted into a foramen. There is a centrale in the carpus (fig. 829), and in the *Chelydridæ* also in the tarsus. The tarsus may probably be regarded as having five distinct tarsalia, as in the Amphibia and *Mesosaurus*. In both the manus and pes there are always five digits, with a variable number of phalangeals. Not unfrequently the bones of the palate develop inferior plates to floor the nasal passage, and thus produce secondary posterior nares with a vertical aperture. Since the palæonto-

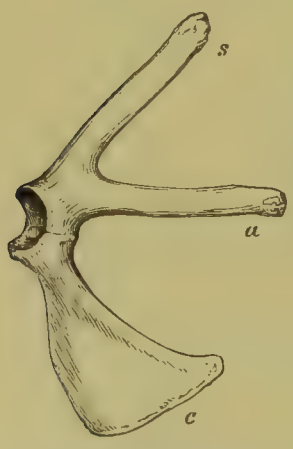


Fig. 1008.—Right side of the pectoral girdle of *Testudo*. *s*, Scapula; *a*, Precoracoid; *c*, Coracoid.

logist generally has to deal with what is frequently and conveniently termed the *shell*,—that is, the carapace and plastron together,—attention must be more particularly directed to its structure in the more typical forms. Commencing with the epidermal skeleton of those forms in which this is fully developed, we find that it consists of horny shields, which usually have their edges in apposition, but occasionally overlap (fig. 1021). On the upper surface there are five *vertebral* shields in the middle line, on either side of which there are four *costals;* while the border has 24 or 25 smaller shields, of which the median anterior one (when present) is termed the *nuchal*, and the double or single posterior shields are known

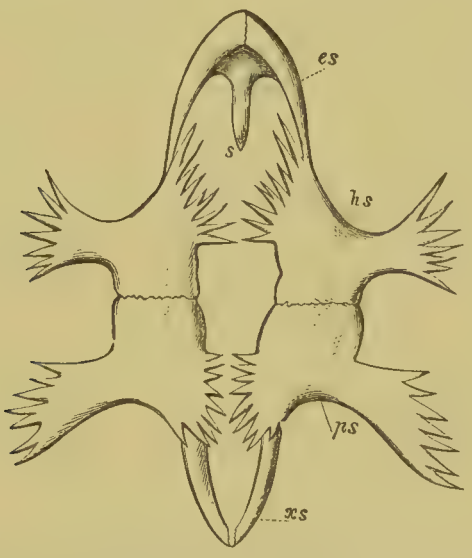


Fig. 1009.—Bones of the plastron of *Thalassochelys caretta*. Much reduced. *es*, Epiplastral (clavicle); *s*, Entoplastral (interclavicle); *hs*, Hyoplastral; *ps*, Hypoplastral; *xs*, Xiphiplastral. (After Owen.)

as the *caudals;* the remaining eleven on either side being reckoned as *marginals*. The position of all these shields is exhibited in fig. 1017. On the ventral aspect of the plastron (fig. 1016) there are usually six pairs of shields, of which the most anterior are termed *gulars*, the next *humerals* (*postgulars*); the next *pectorals;* then the *abdominals;* the *femorals;* and finally the *anals*. In some cases, however, there is an additional *intergular* (very rarely double), which is usually (as in fig. 1012) placed between the gulars, but in some cases may be situated below the gulars, being then surrounded by the gulars, humerals, and pectorals, as in *Chelodina*. In the extinct *Archæochelys*, of the Wealden, where the intergular occupies the latter position, there is also a series of apparently single *interpectoral*, *interabdominal*, and *inter-*

femoral shields dividing the normal pairs of plastral shields; and it is probable that this may be regarded as the archaic type. Similarly in a Chelonian, mentioned below under the name of *Tropidemys*, there is a median series of intervertebral shields dividing the normal vertebrals into two lateral rows. In some cases *inframarginal* shields separate the marginal from the plastral shields.

The bones of the carapace, although following the same general arrangement, do not, as will be seen from the figures, by any means

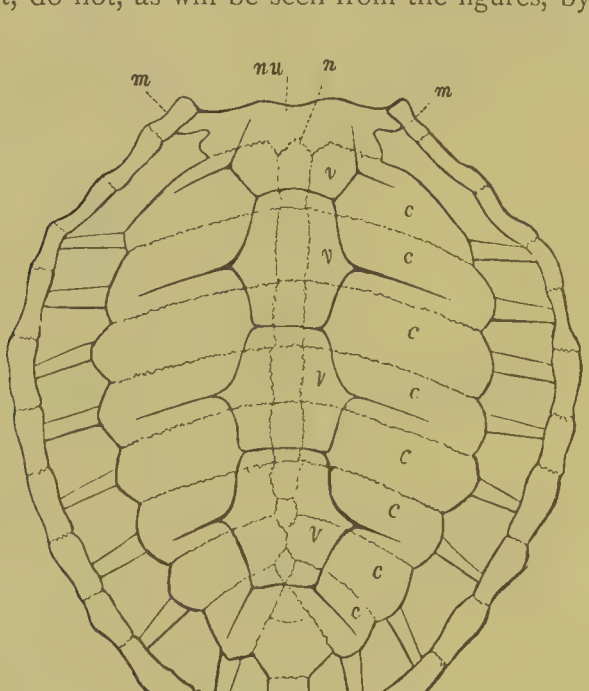


Fig. 1009 *bis*.—Upper surface of the carapace of *Thalassochelys caretta*, with the epidermal shields removed. The dark lines in the middle region indicate the boundaries of the shields, and the sinuous ones the sutures between the bones. *nu*, Nuchal bone; *py*, Pygal do.; the bone above this marked *n* and the next are the suprapygals; above these, the eight neurals, of which the first is marked *n*; *c*, *c*, Costal bones; *m*, *m*, Marginal do.; *v*, *v*, Vertebral shields. Much reduced. (After Owen.)

correspond with the overlying shields. In those forms with a well-developed carapace there are typically (fig. 1017) eight median *neural* bones formed by the expansion of the spines of the dorsal vertebræ (fig. 1010); these being preceded by a *nuchal*, and followed by two or more *suprapygals* and a *pygal*, all of which have no connection with the vertebræ. While, however, the nuchal is a cartilage bone, the pygal and suprapygals are of purely dermal origin. On either side of this median row is a series of from seven to nine

costal bones (fig. 1009 *bis*) formed by the development of a plate on the outer surface of each rib (fig. 1010); while the sides of the carapace are completed by the eleven *marginals*,[1] which are dermal ossifications, and eight of which receive the extremities of the ribs from the second to the ninth. In all young individuals, and in many of the marine Turtles (fig. 1009 *bis*), the costal bones do not extend to the extremities of the ribs, and consequently leave vacuities on the inner side of the marginals, but in the land Tortoises and their allies (fig. 1017) the carapace is entirely bony. In some instances, again, the number of neural bones may be reduced (as in fig. 1014, where there are but seven), and very rarely they are entirely wanting, so that all the costals meet in the middle line. The two suprapygals may also be reduced to one, as in fig. 1014. Similar variations occur in respect to the degree of ossification of the plastron; since

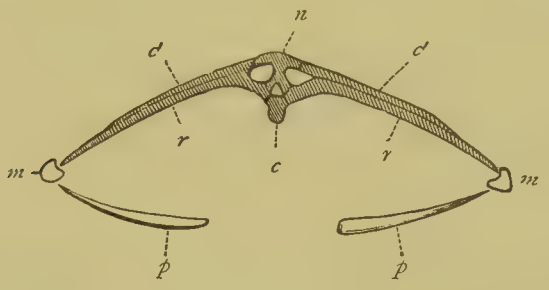


Fig. 1010.—Transverse section through the shell of *Chelone mydas*. Reduced. *c*, Vertebral centrum; *n*, Expanded neural spine; *r*, Rib; *c'*, Costal bone; *m*, Marginal do.; *p*, Plastron. (After Huxley.)

while in all young individuals, and in the existing marine forms (fig. 1009) throughout a great part or the whole of life there are vacuities between the bones, in the land Tortoises and their allies the bones are all connected by suture.

In the marine Turtles the plastron is totally unconnected with the carapace; but in most other forms the hyo- and hypoplastrals send up longer or shorter peduncles underlying the marginals, and in some cases also the costals of the carapace, and thus form well-marked *axillary* and *inguinal buttresses*. These peduncles are longest in some of the existing Pleurodira; while the inward prominence of the buttresses is most marked in the Indian Batagurs.

Considerable variation occurs in the skulls of the different groups, but it can only be mentioned here that in some genera like *Chelydra* and *Chelone* the supratemporal fossa is more or less completely roofed over by the development of plates extending outwards from the parietal and backwards from the postfrontal; this roof being

[1] Occasionally the number of marginals may be increased to twelve or reduced to ten.

most complete among existing forms in *Chelone* and *Dermochelys*, where the parietal joins the squamosal. In such cases, in addition to the inferior temporal arcade formed by the quadrate, quadratojugal, and jugal, as in fig. 1007, there is also a superior arcade constituted by the squamosal and postfrontal. Whereas, however, such arcades in the Crocodilia (fig. 1089) are separated by the infratemporal fossa, in the Chelonia they are in immediate contact.

The feet may either have all the digits free, or enclosed in a common integument to form paddles.

The humerus of existing Chelonians is a very peculiar bone characterised by its extremely prominent globular head; but in certain Jurassic forms (*e.g.*, *Acichelyidæ*) this head was much smaller, so that the bone departs less from a normal type. On either side of this head there is a projecting ridge, of which the radial, or preaxial, one (generally termed the lateral process) corresponds with the deltoid crest of the Crocodilian humerus; while the ulnar or postaxial (mesial) process represents the inner tuberosity of the same. In all Pleurodiran Testudinata the radial process is comparatively small, and the ulnar process placed in the same transverse line as the distal surface of the bone. In many Cryptodira, however, and more especially in the land Tortoises, the radial process forms a thin plate extending towards the ventral aspect, and the ulnar process becomes twisted round to the same aspect; thus causing the pit between the two processes to form a narrow funnel-shaped channel instead of being very broad and open. At the same time the shaft becomes extremely curved. In the marine Turtles, where the shaft is nearly straight, the radial process tends to become aborted, and to attain a position more or less below the head. In the Athecata, which likewise have a nearly straight humerus, the radial process, while descending on the shaft, tends to an excessive development.

In time this order dates from the Upper Trias; and it had attained great development in the Upper Jurassic, from which date it appears to have gone on increasing till the later Tertiary.

Considerable diversity of views obtains as to the classification of the Chelonia, but according to the system now followed in the British Museum it may be divided into the two suborders Athecata and Testudinata.

Suborder 1. Athecata.—This group contains those forms which have been usually regarded as showing the nearest approximation to other Reptiles, and therefore representing the most generalised type of the order. Dr Baur, however, takes the opposite view, and regards them as the most specialised group, which has tended to more or less completely lose the carapace. Before, however, a decisive opinion can be given on this question it must be determined whether the absence of a bony connection in this group between the parietals and pterygoids is to be regarded as an acquired or as an original feature. It may be observed that Dr Baur regards the group as closely allied to the *Chelonidæ*, but if the undermentioned Triassic

genus *Psephoderma* be rightly referred to it, we have at once a great obstacle to the acceptance of his view.

The suborder may be briefly characterised by the circumstance that the carapace is entirely of dermal origin, and quite separate from the vertebræ and ribs, and may consist merely of a series of marginal bones, or of marginals with a single median dorsal row of broad scutes, or of a number of small irregular scutes, with longitudinal rows of larger ones; while the plastron (fig. 1011) has no entoplastral (interclavicular) element. The cranium is characterised by the absence of vertical plates connecting the parietals with the pterygoids. All the forms are of marine habits, and consequently the extremities of the limbs are modified into paddles like those of the *Chelonidæ*.

Before noticing the two established families, it may be observed that the imperfectly known *Psephoderma* of the Upper Trias of Bavaria and England is founded on a specimen which appears to be a carapace of a member of this suborder, although it has been suggested that it is not Chelonian at all. This presumed carapace is formed of a number of polygonal scutes, traversed by longitudinal rows of keeled scutes. Here also may be mentioned the genus *Macellognathus*, founded upon the anterior portion of a toothed mandible from the Upper Jurassic of North America, which Professor Marsh regards as showing affinity with the Chelonia, and which may possibly indicate a generalised family of the present suborder.

Family Protostegidæ.—This family is usually regarded as the least specialised of the two that are yet established, although an opposite view is taken by Dr Baur. The carapace, according to the interpretation of that authority, is represented merely by a row of marginal scutes; but the plastron is strongly developed, and composed of very thick ossifications. The type genus *Protostega* occurs typically in the Cretaceous of North America. It was considered by its describer Professor Cope to have possessed a solid carapace, but the bones which he regarded as probably dorsal appear to belong to the plastron. It was also suggested that the dorsal vertebræ were procœlous, with traces of transverse processes; but these vertebræ are probably referable to the cervical region. The type species attained very large dimensions. An allied form from the Upper Cretaceous of Italy has been described under the name of *Protosphargis* (fig. 1011), but further evidence is required to prove its right to generic distinction from the American form. It has, indeed, been asserted that there were no marginal bones, but according to Dr Baur this is incorrect. In the Cambridge Greensand and the English Chalk there occur humeri of Athecate Chelonians which have been provisionally referred to *Protostega*.

It is uncertain whether the remains from the American Cretaceous described as *Atlantochelys* belong to the last-named genus.

Family Dermochelyidæ.—This family is characterised by having a carapace composed either of a median row of large and broad scutes and lateral marginal rows, or of a mosaic of small irregular scutes, or tessaræ, traversed by longitudinal rows of larger ones. The plastron varies considerably; and the humerus, which is of the flattened type of that of the *Chelonidæ*, is distinguished from that of the preceding family by the great development of its radial pro-

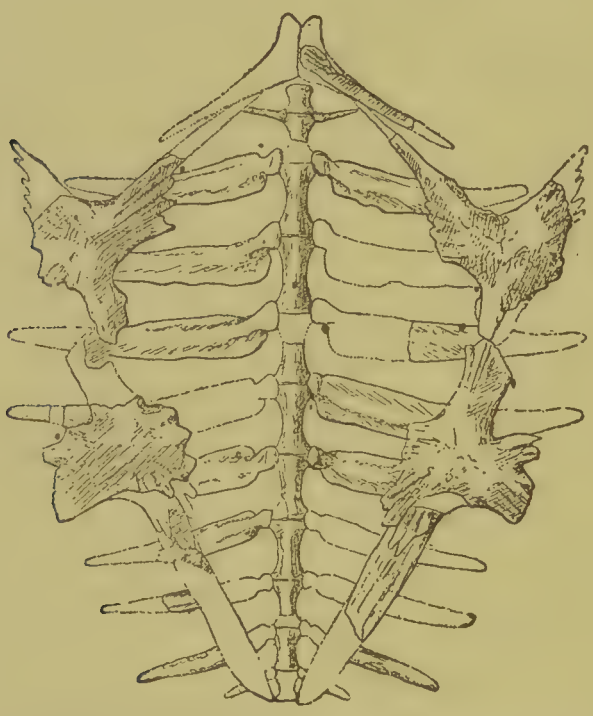


Fig. 1011.—Ventral aspect of the plastron and thoracic region of *Protosphargis veronensis*; from the Upper Cretaceous of Italy. One-fifteenth natural size. (After Capellini.)

cess, which is situated near the middle of the shaft. The skull has the temporal fossæ completely roofed, as in the *Chelonidæ*, and an open tympanic ring, but has no bony floor beneath the narial passage. Whereas all the members of the preceding family are of moderate size, several representatives of the present one attained huge dimensions. The earliest representative is the genus *Eosphargis*, of the London Clay, of which the one known species was originally described as *Chelone gigas*. The skull is of the general type of that of the next genus, but the carapace apparently consists only of a median row of very broad and large carinated scutes, and also of a row of marginals; the structure of the plastron is not definitely

known, but it was doubtless devoid of tessaræ. The allied *Psephophorus*, ranging in Europe from the Middle Eocene to the Upper Miocene, and also found in the Upper Eocene of the United States, is characterised by the presence of a complete tesselated carapace and plastron. In the carapace the longitudinal rows of larger scutes are not carinated, and are more approximated than in the existing genus; the carapace is also thicker than in the latter; and there are larger marginals. It is also suggested that the carapace may have had horny epidermal shields. The skull is short and much depressed. The existing genus *Dermochelys* (*Sphargis*) is represented only by the well-known Leathery-turtle, and is characterised by the absence of a tesselated plastron; by the carination of the scutes of the larger rows of the carapace; by the comparative thinness of the carapace, which is devoid of epidermal shields; and by the longer and more vaulted skull. It is, moreover, worthy of note that in this, as in the preceding genus, there is a distinct nuchal bone at the anterior extremity of the carapace, corresponding to the nuchal of the Testudinata; but there are no marginal ossifications. The one existing species of *Dermochelys* attains a length of nearly five feet, but a species of *Psephophorus* is estimated to have been as much as ten feet in length. The skull of *Eosphargis*, although much larger than that of *Psephophorus*, does not apparently indicate a much larger carapace.

Suborder 2. Testudinata.—This suborder, for which the name Thecophora[1] is also employed, includes by far the great majority of the order, or all those forms commonly known as Tortoises, Terrapins, and Turtles. The group is characterised by the middle region of the carapace being formed of bony plates, developed primarily from the ribs and the neural spines of the dorsal vertebræ, to which it is firmly welded. The outer surface of the carapace is very generally smooth and overlain by horny epidermal shields, but it may be sculptured and devoid of such shields. The parietal bones of the skull in all cases send down vertical descending plates, which may either unite directly with the pterygoids, or be separated therefrom by the intervention of the columella or epipterygoid. It may be observed that in nearly all the Mesozoic forms the vertebral shields are very wide, and that this condition obtains in the young of the later forms. This suborder may be divided into four sections; one, and not improbably two, families of the third section being of marine habits.

Section 1. Amphichelydia.—This section is formed for the reception of certain extinct Chelonians, mostly of Mesozoic age, which combine in a remarkable manner the characters of the two fol-

[1] This name is objectionable, as being employed for an order of Hydroid Zoophytes (*vide supra*, vol. i. p. 203).

lowing sections, and may probably be regarded as the survivors of the earlier ancestral types from which those two sections took origin. They are all characterised by the presence of a mesoplastral bone, and of an intergular shield in the plastron; and the pelvis may or may not be connected with the xiphiplastrals. The entoplastral is rhomboidal. The skull and cervical vertebræ are unknown.

Family Pleurosternidæ.—All the members of this section may be, at least provisionally, included in this family. In addition to the characters given above, it may be observed that the shell is fully ossified, and that the carapace has a complete series of neural bones, of which the hindmost articulates with the anterior suprapygal bone. On the supposition that the Chelonian plastron is derived from a system of abdominal ribs like those of the Rhynchocephalia and Sauropterygia, it will be evident that the mesoplastral of the present group is an archaic feature.

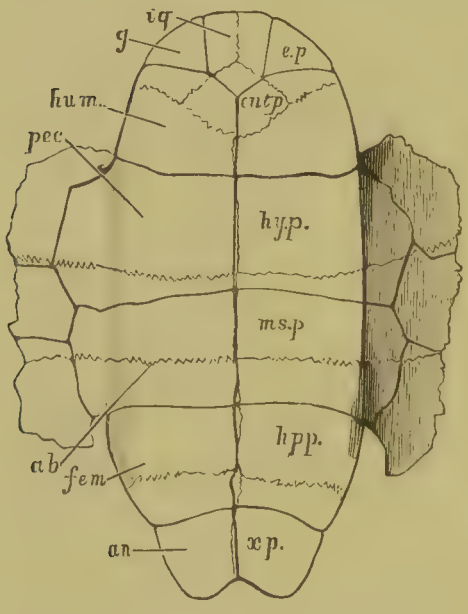


Fig. 1012.—The plastron of *Pleurosternum Bullocki*; from the Purbeck of Dorsetshire. One-third natural size. *ig*, Intergular scute; *g*, Gular do.; *pec*, Pectoral do.; *ab*, Abdominal do.; *fem*, Femoral do.; *an*, Anal do.; *e.p*, Epiplastral bone; *ent.p*, Entoplastral do.; *hy.p*, Hyoplastral do.; *ms.p*, Mesoplastral do.; *hp.p*, Hypoplastral do.; *xp*, Xiphiplastral do.

In the typical genus *Pleurosternum* (*Megasternum* or *Digerrhum*), which occurs commonly in the English Purbeck, and is also found in the Portland Oolite, the shell is broad and depressed, with complete mesoplastrals (fig. 1012), a large and wide entoplastral, a single intergular shield, and no nuchal shield. In the adult the pubis articulates with a smooth facet on the xiphiplastral, thus foreshadowing the complete sutural union which occurs between these bones in the Pleurodira; but in the young it appears that there was no such articulation. The neural bones of the carapace are hexagonal and comparatively long; while the vertebral shields (as in so many of the earlier Chelonians) were relatively wide. Further, inframarginal shields (shown in fig. 1012) were developed between the shields of the plastron and the marginal shields of the carapace; while the extremities of the xiphiplastrals were notched. The bones of the pectoral girdle and the humerus approximate to those of the existing Pleurodiran genus *Chelys*.

Much confusion has arisen in regard to this genus owing to a plastron having been described under the name of *Platemys Bullocki*, under the erroneous impression that it had been obtained from the London Clay. Remains of *Pleurosternum* are extraordinarily abundant in the Purbeck of Dorsetshire; and include specimens of all ages, from the newly hatched young, with a carapace of a couple of inches in length, to adult specimens which are close upon twenty inches. Curiously enough, however, no specimen of the skull seems to have been obtained. The young appears to have differed considerably in the details of the shell from the adult; thus, not only was the pubis, as already mentioned, entirely unconnected with the plastron, but the marginal bones encroached in a remarkable manner upon the front of the nuchal. Moreover, it seems that in very young individuals the vertebral shields were divided in the middle.

In *Helochelys*, of the Lower Greensand of Bavaria, we have another genus also furnished with complete mesoplastrals, but apparently without any articulation between the pubis and the plastron. The shell is ornamented with a pustular sculpture resembling that found in the genus *Tretosternum*, mentioned below among the *Chelydridæ*. The plastron differs from that of *Pleurosternum* in that the xiphiplastrals were not notched; and there appears to have been a nuchal shield.

The next two genera, constituting the family *Baënidæ* of Professor Cope, may be at least provisionally placed here. Both are devoid of a bony attachment between the pelvis and plastron. The genus *Platychelys* (*Helemys*), typically from the Lower Kimeridgian lithographic limestone of the Continent, is readily distinguished by the number of irregular ridges and prominences on the carapace (fig. 1013), and by the width and irregular contour of the neural bones. The mesoplastrals are small, and widely separated in the middle line; and the intergular shield is single.

The genus *Baëna*, from the Eocene of the United States, has the mesoplastrals meeting only by a point in the middle; and is further remarkable for the presence of double intergular shields, and the presence of a small additional costal shield in advance of the normal first costal. The caudal vertebræ are opisthocœlous. Professor Cope, who places this genus in the Cryptodira, regards it as indicating a generalised type, showing marked signs of affinity with the Pleurodira, and exhibiting traces of an imperfect connection between the pelvis and the plastron. The extinct North American genus *Polythorax* should perhaps be also placed in this family, although it is not certain that it is not allied to the Cryptodiran *Adocus*.

Here also may be mentioned the very imperfectly known genus *Archæochelys*, of the English Wealden, in which, as observed above,

the paired shields of the plastron were separated by a median series of azygous shields, which probably extended backwards from the intergular to the extremity of the xiphiplastral. If the separate bones are rightly interpreted, it would appear that the plastron had a mesoplastral element, which, instead of being situated in the middle of the bony bridge as in *Pleurosternum* (fig. 1012), and taking no part in the formation of the axillary notch, formed the anterior part of this bridge and the whole of the notch. The hyoplastral would therefore be entirely above the latter notch, as in the existing Pleu-

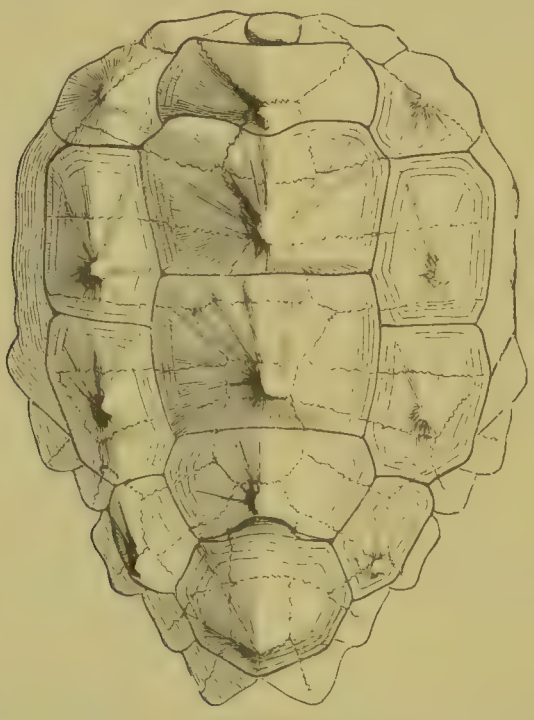


Fig. 1013.—Carapace of *Platychelys Oberndorferi*; from the Lower Kimeridgian of Bavaria. One-third natural size. (After Wagner.)

rodiran genus *Sternothœrus*. Possibly also a Chelonian, from the Lower Jurassic of Stonesfield, described, upon the evidence of the impressions of the epidermal shields of the carapace, under the name of *Testudo Stricklandi*, should also find a place in this group. The name *Protochelys* may be proposed for this form, which has certainly nothing to do with *Testudo*.

Section 2. Pleurodira.—The members of this section are, as a rule, characterised by the complete ossification and union of the carapace and plastron, and by the full development of the marginal bones, which are connected with the ribs, as well as by the sutural union or anchylosis (synostosis) of the pelvis with both the carapace and the xiphiplastral part of the plastron. Very frequently the first

suprapygal bone, and some (fig. 1014) or occasionally all of the neural bones are absent; and when epidermal shields are developed an intergular (as in fig. 1012) is present on the plastron. This shield is, however, sometimes found in the next section, in which the neurals may also be reduced in number. The entoplastral bone (as in the preceding section) is either oval or rhomboidal; and a mesoplastral bone (compare fig. 1012) may be present.

In the skull of existing and Tertiary types the tympanic cavity is completely surrounded by the quadrate, which forms an unbroken ring; the articular surface of the quadrate has a concavity for the reception of a condyle on the mandible; the pterygoids are very broad and wing-like; the vomer may be absent, so that the palatines may meet in the middle line; and there may be distinct nasals, and a suture in the mandibular symphysis. The cervical vertebræ have well-developed transverse processes, and single terminal articulations; while there are never more than three phalangeals to the digits.

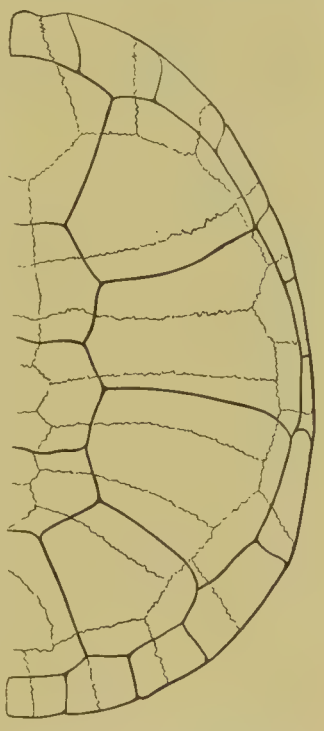


Fig. 1014.—The right half of the carapace of *Sternothærus nigricans*; from Madagascar. The thick lines indicate the boundaries of the epidermal shields.

The Pleurodira are further characterised by their inability to retract the head directly within the carapace; but the neck is bent on one side and the head thus brought within the margin of the shell. In all cases the labyrinth of the ear is completely open from behind.

At the present day this section is almost exclusively confined to the southern hemisphere; but in the Eocene forms more or less nearly allied to existing types were widely spread over the northern hemisphere, and in the Mesozoic there were many European representatives of the group. With the exception of *Podocnemis*, the existing forms are carnivorous, and the whole of them are thoroughly aquatic.

At least one of the two earliest known genera of Testudinata has been referred to this section; and from the occurrence in many existing forms of separate nasals, and of a mesoplastral bone, we may regard this section as retaining evidence of a close alliance with a primitive generalised type which has been lost among existing Cryptodira, since it is nearly certain that features like these if once lost would not reappear, except as abnormalities. The presence of transverse processes to the cervical

vertebræ would also seem to be a generalised character; and, from the evidence afforded by the above-mentioned *Pleurosternum* and *Archæochelys*, the presence of an intergular shield should probably be likewise regarded in the same light. The anchylosis of the pelvis to the plastron, as pointed out by M. Dollo, would, however, seem to prevent us from regarding the Pleurodira as the ancestors of the Cryptodira; and it is more probable that both sections should be regarded as divergent branches of a common stock, probably represented by Amphichelydia of earlier age than those yet known.

It would seem probable that the palate of the earlier Mesozoic Pleurodirans approximated to the Cryptodiran type, and that the peculiar mandibular articulation and closed tympanic ring of the existing forms are acquired features. The skull of the Mesozoic types appears generally to have been roofed over after the fashion of the modern Turtles; this structure having apparently been common to many of the earlier forms of both this and the following sections of the suborder.

Family Proganochelyidæ. — This name is proposed by Dr Baur for the reception of the genus *Proganochelys*, from the Keuper of Würtemberg, which he regards as a Pleurodiran, although differing from all other members of the section in that the plastron unites only with the edges of the marginals, without giving off axillary and inguinal buttresses. It is suggested that mesoplastral bones were present, while the carapace is compared to that of *Platychelys*. The latter resemblance suggests that this form might belong to the Amphichelydia, but a study of the figure of the type specimen given by Professor Quenstedt, under the synonym of *Psammochelys*, shows that its extremely imperfect nature scarcely permits any decisive opinion to be formed as to its true affinities. Whether the imperfectly known and apparently aberrant genus *Chelytherium* of the Keuper is an allied form cannot yet be determined.

Family Plesiochelyidæ.—This Mesozoic family is characterised by the total absence of the mesoplastral element in the plastron, and also by the circumstance that the pubis alone is united with the xiphiplastral; while there may or may not be a complete series of neural bones articulating posteriorly with the suprapygal. The plastral shields are separated from the marginals by the intervention of a series of inframarginals; and the plastron, as in the succeeding families, is connected by long buttresses with the carapace. The humerus is of the type found in existing Pleurodira; and the second digit of the manus, when known, has but two phalangeals. The skull is known only in a few cases with certainty.

The typical genus *Plesiochelys* and the closely allied *Craspedochelys* were originally described from the Lower Kimeridgian Lithographic limestones of Bavaria and France. These genera have a thick shell, with the full complement of neural bones, which posteriorly join the first suprapygal, and with the vertebral shields of the carapace of moderate width. The entoplastral bone is relatively wide and

rounded; the nuchal is but slightly emarginate; and the intergular shield is double. The surface of the carapace is usually marked by flutings. Some at least of the Chelonians from the Kimeridgian of Hanover which have been described under the preoccupied name of *Stylemys* may be included in *Plesiochelys*, and this genus is also represented in the English Wealden.

Allied Chelonians, from the Kimeridgian of Hanover, described under the name of *Chelonides* (likewise preoccupied), not improbably indicate forms connecting *Plesiochelys* with the undermentioned *Hylæochelys*. In one specimen referred to the type species of *Chelonides*, there are but seven neural bones; but the vertebral shields are narrower than in typical species of *Hylæochelys*. If these forms are really entitled to rank as a distinct genus they require a new name. A skull said to have been associated with the shell of the type species of *Chelonides* has the temporal fossæ roofed over by bone, while the palatines are described as meeting in the middle line after the manner of many existing Pleurodira. From the occurrence of *Plesiochelys* and the undermentioned *Hylæochelys* in the Wealden, and the apparent rarity of the *Acichelyidæ* in the same beds, it is probable that the members of this family were of freshwater habits.

It is probable that the genus *Parachelys* of the Lithographic Limestone (which was considered by Professor von Zittel to be indistinguishable from *Acichelys*) is really identical with *Plesiochelys;* in which case the former name should supersede the latter, and the family name *Parachelyidæ* replace *Plesiochelyidæ*. The humerus of this genus resembles that of recent Pleurodira, and is widely different from that type of humerus which appears to be referable to the *Acichelyidæ*. The number of the phalangeals in the digits of the manus of this form (and also in *Idiochelys*) is 2, 2, 3, 3, 3; and this presents a decided approximation to the existing Pleurodiran genus *Pelomedusa*, which differs from all other freshwater forms now living in that there are only two phalangeals in each digit.

The name *Hylæochelys* has been proposed for an allied genus of Chelonians typically represented by the so-called *Pleurosternum latiscutatum* of the English Purbeck, which as shown by a shell from the Wealden preserved in the British Museum, belongs to the present family. This genus is distinguished from *Plesiochelys* by the much wider vertebral shields of the carapace, in which the width may exceed three times the length; and also by the narrower and diamond-shaped entoplastral bone; as well as by the circumstance that the neural bones, at least usually, do not join the suprapygals, and are generally interrupted in the middle of the series; while the hypoplastral bone is relatively shorter. Both in this and the preceding genus there may be a vacuity in the middle of the plastron.

It would appear that the Purbeck form described as *Pleurosternum emarginatum*, as well as the Wealden specimens to which the names *Chelone Belli* (*costata*), and *Platemys Dixoni* and *Mantelli* have been applied, are likewise referable to *Hylæochelys*. It is, moreover, very probable that a Chelonian, from the Upper Greensand of Kent, to which the name *Plastremys* has been given without description, is also referable to this genus.

The genus *Idiochelys* (*Chelonemys*) and the allied *Hydropelta*, of the Lower Kimeridgian of the Continent, would appear to be closely allied to the preceding. *Idiochelys* resembles *Hylæochelys* in its extremely wide vertebral shields, and also in its small and diamond-shaped entoplastral bone, but differs in that the number of neural bones is generally much reduced, so that many of the costals meet in the middle line; while there are also differences in the contour of the lower plastral shields. This genus, which is known only by immature specimens, was indeed regarded by Professor Rütimeyer as essentially Pleurodiran, although there was no absolutely decisive evidence in support of this view. The shell is thinner than in *Plesiochelys*; and the skull has the temporal fossæ roofed over by bone, and apparently had a long sutural union between the postfrontal and parietal.

Mesozoic Chelonians of Uncertain Position.—It will be convenient to notice in this place several Mesozoic Chelonians mostly known to us only by the skull, of which the serial position cannot at present be determined. A large skull from the Portland Oolite, originally described as *Chelone platyceps*, but subsequently made the type of the provisional genus *Stegochelys*, is characterised by the incomplete roofing of the temporal fossæ, and the meeting of the prefrontals in the middle line, while it is stated to have distinct nasals. The palate is unknown. The size of this specimen suggests that it may perhaps be referable to the Cryptodiran genus *Thalassemys* of the Kimeridgian.

In the Wealden of Belgium there occur remains of young Chelonians to which the name *Chitracephalus* has been applied. There is no mesoplastral bone; and the skull is characterised by its elongated form, open temporal fossæ, and the approximation of the orbits to the nares.

In the Upper Cretaceous genus *Rhinochelys* the shell is only known by fragments. The skull (fig. 1014 *bis*) has an inferior temporal arcade, the temporal fossæ are completely roofed over, the palatines meet in the middle line, the nasals are distinct from the prefrontals, which are separated from one another by the frontals, the pterygoids are comparatively narrow, and laterally emarginate, while the symphysial suture of the mandible is obliterated. The humerus is of the Pleurodiran type found in *Para-*

chelys. It has been suggested that this genus is Pleurodiran; and if this prove to be the case it will be interesting as showing an approximation in several cranial features to the Cryptodira. In its complete roof the skull of this genus approximates to the *Chelonidæ*. Remains of *Rhinochelys* are very abundant in the Cambridge Greensand, and they are also met with in the Gault and the Lower Chalk. Fragmentary Chelonian shells from the Cambridge Greensand, to which the name *Trachydermochelys* has been applied, are not improbably referable to this genus. They are characterised by their pustulate external surface; the pustules being much larger than in the Amphichelydian genus *Helochelys* of the Lower Greensand. A somewhat similar, although less marked, pustulation occurs in the existing *Chelodina*.

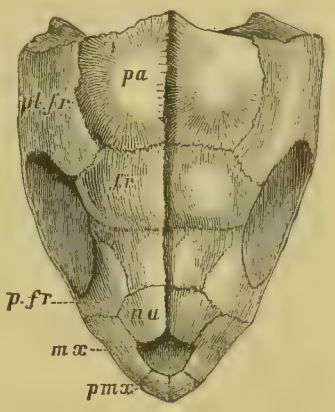


Fig. 1014 *bis*. — The cranium of *Rhinochelys cantabrigiensis*, imperfect posteriorly; from the Cambridge Greensand. *pa*, Parietal; *pt.fr*, Postfrontal; *fr*, Frontal; *p.fr*, Prefrontal; *na*, Nasal; *mx*, Maxilla; *pmx*, Premaxilla.

Family Pelomedusidæ. — Reverting to the consideration of undoubted Pleurodirans the present existing family agrees with the Amphichelydian *Pleurosternidæ* in the presence of mesoplastral bones, but is distinguished in that both the pubis and ischium have a sutural union with the xiphiplastral. The shields of the plastron, as in the next family, are in contact with the marginals, owing to the absence of inframarginals. The skulls of existing types have an infratemporal arcade, and in *Podocnemis*, alone among existing representatives of the section, the temporal fossæ are roofed over; moreover, the prefrontals are in contact in the middle line and are fused with the nasals; the palatines, owing to the absence or abortion of the vomer, meet; and the suture between the dentary bones of the mandible is obliterated. The second cervical vertebra is amphicœlous; and the neck is completely retractile within the shell. Further, the series of neural bones, as in the next family, is incomplete and is not connected with the suprapygals. Finally, in both this and the next family the characters of the tympanic and palatal regions of the skull are those mentioned at the commencement of the description of the Pleurodira. The earliest known representatives of this family occur in the Upper Cretaceous of the United States, where we meet with forms apparently closely allied to the existing *Podocnemis*. The genus *Bothremys* has been described upon the evidence of a skull from those deposits; while the name *Taphrosphys* has been applied to portions of the carapace and

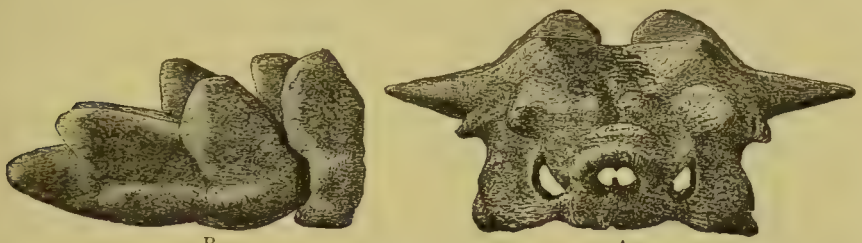
plastron which not improbably belong to the same form. *Bothremys* differs from *Podocnemis* by the presence of a distinct vomer. It is not improbable that allied forms occur in the Cretaceous of New Zealand. The only existing genus which appears to be represented in a fossil state is the above-mentioned *Podocnemis*, of South America and Madagascar, which occurs in the London Clay and the Eocene of Northern India. This genus includes the largest existing representative of the section. The carapace has seven neural bones, and the mesoplastrals are small, and do not meet in the middle line. The shell of a large Chelonian from the London Clay, which has been referred to this genus under the name of *P. Delabechei*, may not improbably belong to the genus *Dacochelys*. The latter is founded on a mandibular symphysis from the same deposits which is characterised by a large spine-like process on its oral surface, and the serrated margins of the alveolar borders. Its serial position depends on whether it is specifically identical with the above-mentioned shell.

Family Chelyidæ.[1]—In this family the shell is much thinner than in *Plesiochelys*, and is characterised by the absence of the mesoplastrals, and the reduced number of neural and suprapygal bones; while both the pubis and ischium unite with the plastron. The skull has an incomplete inferior temporal arcade, owing to the absence of the quadratojugal; and is further distinguished by the separation of the prefrontals by the frontals; the distinct nasals (except in *Chelys*); by the vomer dividing the palatines; and by the persistence of the suture in the mandibular symphysis. The temporal fossæ are open, but there is an arch connecting the parietal with the squamosal, not found in the *Pelomedusidæ*, and which is probably a remnant of the earlier type of roof. The fifth and eighth cervical vertebræ are biconvex. The neck cannot be fully retracted within the carapace. As typical genera we may notice the South American *Chelys*, *Hydraspis*, and *Platemys*; and the Australian *Chelodina*, *Emydura*, and *Elseya*, in which neural bones are absent. Remains of *Chelodina* and *Emydura* occur in the Pleistocene of Australia; while *Hydraspis* is found in a fossil state in the Lower Eocene of India, and *Platemys* has been recorded from the Cretaceous of North America.

Family Miolaniidæ.—This is an extinct family represented only by the remarkable *Miolania*, from the Pleistocene of Australia, of which the remains were originally referred to the large *Varanus* of the same deposits. This family, according to Mr Boulenger, occupies a position in the present section somewhat analogous to that filled by the *Chelydridæ* among the Cryptodira; the caudal vertebræ

[1] Frequently incorrectly given as *Chelydidæ*.

being opisthocœlous and the temporal fossæ of the cranium roofed over by bone. The cranium (fig. 1015) is remarkable for carrying several pairs of horn-like processes (on which account the name *Ceratochelys* has been proposed); and the tail was protected by a nodose bony sheath (fig. 1014), somewhat resembling that of the Glyptodont Edentates. The species of which the skull is shown in the woodcut must have attained huge dimensions. The carapace and plastron are known only by fragments. From the structure of



B A

Fig. 1015.—*Miolania Oweni.* A, Anterior view of cranium; B, Right lateral aspect of the extremity of the caudal sheath; from the Pleistocene of Australia. Much reduced. (After Owen.)

the jaws it is inferred that *Miolania* was herbivorous; while the form of the terminal phalangeals and the solid caudal sheath are indicative of terrestrial habits. The bones of the pelvis are fused into an innominate bone, and some of the cervical vertebræ had two transverse processes.

It should be observed that Dr Baur dissents from the view that this genus is a Pleurodiran, and would refer it to the Cryptodiran family *Testudinidæ;* but there appear to be several misconceptions in the arguments adduced in support of this view. Sir R. Owen does not, indeed, recognise the Chelonian nature of *Miolania*, and regards it as constituting a distinct group, under the name of Ceratosauria; but this view is altogether at variance with the facts, and there can be no question but that the genus is a true Chelonian.

Family Carettochelyidæ.—The last family of the Pleurodira is characterised by the absence of horny shields, and is typically represented by *Carettochelys* of New Guinea, in which the neural bones are very small and do not touch one another, and the limbs are paddle-shaped. In the Lower Eocene of Northern India we find the extinct genus *Hemichelys*, which differs from *Carettochelys* in having seven large neural bones in contact with one another; the nature of the limbs being unknown.

Section 3. Cryptodira.—In this section the ossification of the carapace and plastron may be either imperfect or complete, and the two may or may not be connected at their edges; there is no bony attachment of the pelvis to the plastron; and as a general rule, the

full complement of suprapygal and neural bones is present, although there are numerous exceptions. Excluding the Amphichelydian forms, no known Cryptodiran has a mesoplastral bone, while in the majority of cases, especially among existing types, the plastron has no intergular shield (fig. 1016). The entoplastral, when present, is either ovoid, rhomboidal (fig. 1016), or †-shaped (fig. 1009), and the epiplastral joins the hyoplastral. In the skull (fig. 1007) the outer border of the tympanic cavity is always deeply notched posteriorly; the quadrate articulates with a concavity in the mandible; and the pterygoids are comparatively narrow and laterally emarginate. There are never more than three phalangeals in the digits. The sacral and caudal ribs (as in the Pleurodira) articulate partly with the centra and partly with the arches of the vertebræ; while the cervical vertebræ have very imperfectly developed transverse processes. No existing Cryptodiran has distinct nasals, and at present there is no decisive evidence of the presence of these bones in any fossil form.

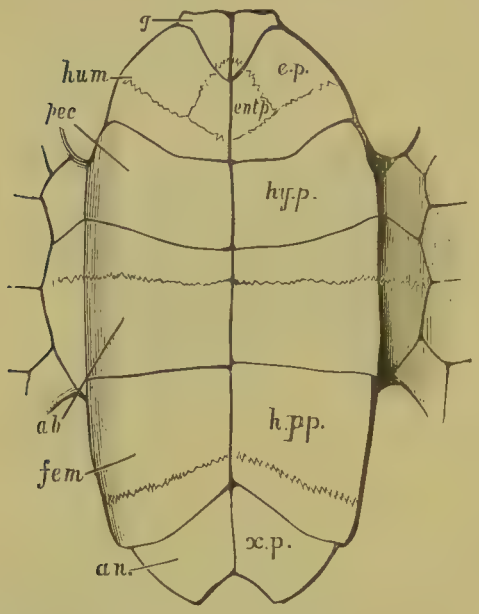


Fig. 1016.—Plastron of *Kachuga tectum*; from India. One-half natural size. *g*, Gular shield; *hum*, Humeral do.; *pec*, Pectoral do.; *ab*, Abdominal do.; *fem*, Femoral do.; *an*, Anal do.; *e.p*, Epiplastral bone; *ent.p*, Entoplastral do.; *hy.p*, Hyoplastral do.; *h.pp*, Hypoplastral do.; *x.p*, Xiphiplastral do.

The Cryptodira are further characterised by their power of retracting the head by a sigmoid curvature of the neck in a vertical plane directly within the carapace. This large section comprises the great majority of the existing Testudinata, and at the present day is mainly characteristic of the Northern Hemisphere, being totally absent from Australia. The habits of existing Cryptodires may be carnivorous or herbivorous, and either terrestrial, fluviatile, or marine.

Family Acichelyidæ.—Under this name may be grouped a number of generalised Cryptodirans often spoken of as the *Thalassemydes*, and in some cases as the *Eurysternidæ*. They occur typically in the Lower Kimeridgian Lithographic Limestones of the Continent, and are abundant in the Kimeridge Clay, while they survived till the period of the Lower Greensand. They were probably mainly of marine habits, since they appear to be very rare in the

freshwater Purbeck and Wealden beds. They are characterised by the more or less heart-shaped carapace, of which the costals are often imperfectly ossified, and do not unite completely with the marginals. The plastron has, moreover, a vacuity in the centre, which persists for a long period or throughout life, but it had large axillary and inguinal buttresses for connection with the carapace. The humerus has a very imperfectly developed head and a slightly curved shaft; and the limbs were not modified into paddles. The nuchal bone of the carapace has no costiform processes; and the temporal fossæ of the skull were more or less completely roofed over by bone.

In their cordiform, and frequently imperfectly ossified carapace, the *Acichelyidæ* agree with the modern *Chelonidæ;* and since the peculiar form of the neurals of *Tropidemys* is another feature only met with elsewhere in the latter family, there are strong grounds for regarding the one family as the direct ancestor of the other. This family also exhibits certain signs of affinity with the Pleurodiran *Plesiochelyidæ;* while the simplicity of the humerus is a very generalised character.

The genus *Thalassemys*, which includes some very large forms, is characterised by its long and flat neural bones, in which the anterior lateral surfaces are much shorter than the posterior ones; while the vertebral shields are narrow. The carapace is well ossified, and of considerable thickness. The type species occurs both in the Lithographic Limestone and the Kimeridge Clay of England; the undescribed Chelonian from the latter deposit at Ely, to which the name *Enaliochelys* has been applied, being apparently identical. As already mentioned, the Portlandian *Stegochelys* may likewise be the same; and the genus is represented in the Dorsetshire Purbeck. In the typical genus *Acichelys* (*Eurysternum*,[1] *Achelonia*, *Palæomedusa*, or *Aplax*) the neural bones of the carapace are flat, with short and often indistinct antero-lateral surfaces, and the costals are well ossified, the vertebral shields of the carapace being comparatively wide. This genus seems to be confined to the Lithographic Limestone.

In *Pelobatochelys*, of the Kimeridge Clay, we have a large form with a very imperfectly ossified carapace, in which the costals are extremely thin, and the neural bones are long and six-sided. The antero-lateral surfaces of the neurals are much shorter than the postero-lateral, and in the fifth neural the latter surfaces are deeply excavated. The neurals, especially in the hinder part of the carapace, are strongly ridged, having the form of the ridge-tiles of a roof; and the hinder part of the whole carapace is itself roof-like. The vertebral epidermal shields were very wide, and the borders of

[1] This name is the earliest, but is preoccupied.

the areas which they overlie on the carapace are conspicuously fluted. The last genus, *Tropidemys*, while having the roof-like posterior neurals of *Pelobatochelys*, is distinguished by the almost regularly hexagonal form of these bones, owing to the lengthening of the anterior and the shortening of the posterior lateral surfaces. One species from Hanover referred to this genus shows the unique feature of a median row of numerous small intervertebral shields dividing the normal vertebrals into two lateral series. This genus occurs in the Lithographic Limestone, in the English Kimeridge Clay, and the Lower Greensand of Switzerland (*T. valanginiensis*). The detached neurals are readily distinguished not only by their shape, but by their excessive thickness.

Family Chelydridæ.—This family is confined at the present day to North, and part of South America, where it is represented by the Alligator-terrapins (*Chelydra*), and the larger Snapper (*Macroclemmys*). The skull is more or less triangular, and very broad behind; the temporal fossa is partially roofed over, but the squamosal is widely separated from the parietal; the bones of the palate do not develop plates to floor the narial passage; and the tympanic ring of existing forms, like that of the *Testudinidæ*, is in great part closed behind. The nuchal bone of the carapace develops a long rib-like (costiform) process on either side, which underlies the marginals; and the complete union of the marginals with the costals does not take place for a long period; while in the plastron vacuities frequently persist till late in life, and the plastron itself may be relatively small, and unites with the carapace by gomphosis, the hyo- and hypoplastrals not giving off buttresses to underlie the carapace. In existing forms the caudal vertebræ are opisthocœlous; and there is no bony union between the ischium and pubis of the same side to enclose an obturator foramen. The head cannot be completely retracted within the shell. The humerus is not flattened, and has its radial and ulnar processes large, and directed towards the ventral aspect.

If all the genera provisionally included in this family are rightly referred, it will be the oldest representative of the order which still exists. The genera may be divided into three subfamilies, according to the presence or absence of sculpture or epidermal shields on the shell. It is, however, by no means certain that all these forms should be included in this family; but until we know the skull and caudal vertebræ of all the genera it is impossible to decide this point, and it may eventually prove that there is a more or less complete passage to the *Dermatemydidæ* from this family, since there already are some indications of a connection between them. Thus the American Cretaceous genus *Toxochelys* is stated by Dr Baur to be a true Chelydroid, but to have the procœlous caudal vertebræ

of *Dermatemys*, and also to have an open tympanic ring. The *Anostirinæ* are typically represented by *Anostira*, of the Upper Eocene of North America and England, and we may probably include in the same group *Pseudotrionyx* (*Apholidemys*), of the Middle and Lower Eocene of Europe. In these forms the shell has a vermiculated sculpture, but epidermal shields appear to be absent, although Dr Baur states there are traces of them in the typical genus; the plastron is well developed; and the neural bones are reduced to seven, as in *Dermatemys*. *Anostira*, which, on account of the presence of only ten marginal bones, Dr Baur places in the *Dermatemydidæ* (*Staurotypidæ*), differs from *Pseudotrionyx* by the sculpturing of the neural bones. The skull of *Pseudotrionyx*, originally referred by Sir R. Owen to *Platemys*, agrees essentially with that of *Macroclemmys*, although the orbits are less lateral. The second subfamily, *Tretosterninæ*, is represented by *Tretosternum*, of the English Wealden and Purbeck, with which *Peltochelys*, of the Wealden of Belgium, is identical. Possibly the imperfectly known North American Cretaceous genus *Compsemys* may prove to be a closely allied, if not identical, type. The shell is studded with granular tubercles, and has epidermal shields; while the plastron is larger than in the *Chelydrinæ*, and has an intergular shield. This is, however, accompanied by only five paired plastral shields, as in *Dermatemys*, instead of the six found in *Pleurosternum* (fig. 1012). The nuchal bone is deeply emarginate.

Finally, in the typical subfamily *Chelydrinæ* the shell is not sculptured, and has epidermal shields; the plastron is relatively small, and generally has a median vacuity; while there is the full number of eight neural bones, of which the last articulates with a suprapygal, and thus prevents any of the costals from meeting in the middle line. The type genus *Chelydra* is represented in the Puerco or Lowest Eocene of the United States, and also occurs in the Upper Miocene of Switzerland, the Middle Miocene of Styria (where it has been described as *Chelydropsis*), and the Lower Miocene of Rott, near Bonn. No fossil forms have hitherto been referred to *Macroclemmys*, which is distinguished from *Chelydra* by the more deeply emarginate nuchal, and the lateral orbits of the skull, which is very large in proportion to the shell and limb-bones.

Family Cinosternidæ.—With the American genus *Cinosternum* we come to a family readily distinguished by the total absence of the entoplastral element of the plastron. In the existing genus the skull has open temporal fossæ, the nuchal has a costiform process like that of the *Chelydridæ*, the pelvis is of a Testudinate type, and the caudal vertebræ are procœlous. The absence of the entoplastral also occurs in the Swiss Eocene genus *Dithyrosternum*, which has accordingly been placed in the same family. It is distinguished from

Cinosternum by the presence of eight neural bones, and the long bridge connecting the carapace with the plastron.

Family Dermatemydidæ.—The genus *Dermatemys*, of Central America, is taken as the type of a family which includes *Staurotypus* of the same region, and in some respects connects the *Cinosternidæ* with the *Chelydridæ*. The nuchal bone has a costiform process, as in both those families; the temporal fossæ of the skull are not roofed over; the caudal vertebræ are procœlous; and in the pelvis the pubis and ischium of the same side do not unite to enclose an obturator foramen. The shell is well ossified, but in the type genus the union between the costals and marginals does not take place till a late period. *Baptemys*, of the Upper Eocene of North America, which has been included by Professor Cope in *Dermatemys*, is distinguished from the latter by having the full number of neural and suprapygal bones, so that none of the costals meet in the middle line. Here may be mentioned several allied North American forms, most of which are referred by Professor Cope to a distinct family—the *Adocidæ*—mainly on account of the circumstance that the ribs do not develop heads to articulate with the vertebræ; but since the same feature occurs in *Testudo* among the *Testudinidæ*, it cannot be regarded as of family value. In *Homorophus*, of the American Cretaceous, there is no intergular shield, and the vertebral shields are very narrow. In *Adocus*, of the Upper Cretaceous, and *Agomphus* (with which Dr Baur states *Amphiemys* is identical), of the Eocene, intergular shields were present. The former has traces of sculpture on the shell; while in the latter the epidermal shields are very thin, and the surface of the shell is marked with a faint vermiculate sculpture. We are thus led on to the European *Trachyaspis*, which is probably an allied form, and with which one or other of the American types may perhaps prove to be identical. This genus, which has elongated vertebral shields recalling those of *Dermatemys* and *Baptemys*, occurs typically in the European Tertiary, and has also been recorded from the Lower Greensand of Switzerland, although the latter form has been referred by Professor Rütimeyer to *Plesiochelys*. A nearly entire carapace has also been obtained from the Tertiary of Egypt. The surface of the shell is covered with a distinct vermiculated sculpture like that of *Trionyx*, but thin epidermal shields were present.

Family Platysternidæ.—The existing Burmese genus *Platysternum* is represented by a very small Chelonian forming the only member of a family which connects the *Chelydridæ* with the *Testudinidæ*. Thus the temporal fossæ of the skull are roofed over, the pelvis is of a Chelydroid type, and the caudal vertebræ are mostly opisthocœlous; but the nuchal agrees with that of the *Testudinidæ* in having no costiform process.

Family Testudinidæ.—Following Mr Boulenger's arrangement, this extensive family is taken to include the *Cistudinidæ* and most of the *Emydidæ* of other writers, and may be briefly characterised as follows: The limbs terminate in free digits; epidermal horny shields are always present, but there is no intergular shield; the carapace is ovoid and fully ossified; the plastron in the adult is connected with the carapace either by suture or a straight articulation, and is always fully ossified. There is no costiform process to the nuchal bone; the temporal fossæ of the skull are not roofed over by bone; the caudal vertebræ are procœlous; and the pubis and ischium of either side unite to enclose an obturator foramen. The humerus has a well-developed head, and its shaft is more or less curved. The skull is of nearly equal width throughout its post-orbital portion. The Terrapins and Tortoises, as the existing members of this family are commonly termed, exhibit great variety of habits, some being aquatic and others terrestrial; while some, again, are carnivorous and others herbivorous. Some of the terrestrial forms have the normal two epidermal caudal shields of the carapace fused together into a single large shield.

We may commence our brief survey of this large family with the Oriental group of Batagurs, represented by *Batagur*, *Kachuga*, *Hardella*, and allied types. These include freshwater Terrapins, frequently of large size, characterised by the great development of the axillary and inguinal buttresses of the plastron, which divide the sides of the carapace into chambers, and also by the presence of one or more strong ridges on the oral surface of the palate, running parallel to its alveolar borders. On the plastron (fig. 1016) the sulcus between the humeral and pectoral shields is below the entoplastral. *Kachuga* (including *Pangshura*) has the fourth vertebral shield elongated, and overlying parts of four or five neural bones; the anterior neurals being elongated and hexagonal, with the short side anterior. The typical *K. lineata*, in which the fourth vertebral shield is broad anteriorly, is represented in the Pliocene Siwaliks of India, which also yield the existing *K. dhongoka*. In a second group (*Pangshura*), in which the fourth vertebral shield is narrowed to a point at its junction with the third, we have the existing *K. tectum* (fig. 1016) in the Pleistocene and Pliocene of India. *Hardella* (fig. 1017) is characterised by the shortness of the fourth vertebral shield, which usually extends over three neural bones (four in the figure), and by the third vertebral shield overlying parts of three (in place of two) neurals. It is represented in the Siwaliks by the existing *H. Thurgi* (fig. 1017). With the existing American genus *Chrysemys* we come to forms in which the axillary and inguinal buttresses are much less developed than in the Batagurs, and the neural bones are shorter than in *Hardella*.

In *Chrysemys* itself the sulcus between the humeral and pectoral shields of the plastron is situated entirely on the hyoplastral, as in fig. 1016; and from the presence of this feature, it is probable that the so-called *Emys testudiniformis* and *E. bicarinata*, of the London Clay, should be referred to this genus. In the existing genus *Ocadia*, from China, and also in the Palæarctic and North American *Clemmys*, the humeropectoral sulcus is placed somewhat more anteriorly, and consequently cuts the entoplastral bone. A similar feature is frequently found in the so-called *Emys crassa* (*hordwelliensis*), of the Upper Eocene of Hampshire; and it appears that this form should be referred to the genus *Palæochelys*, of the German Miocene, from which *Ocadia* is probably not separable. *Emys wyomingensis*, of the Upper Eocene of North America, appears to be referable to the same genus. *Ocadia*, it may be observed, agrees with the herbivorous Batagurs in the presence of ridges on the palate; but these ridges are absent in *Clemmys* and the undermentioned forms, which are purely carnivorous.

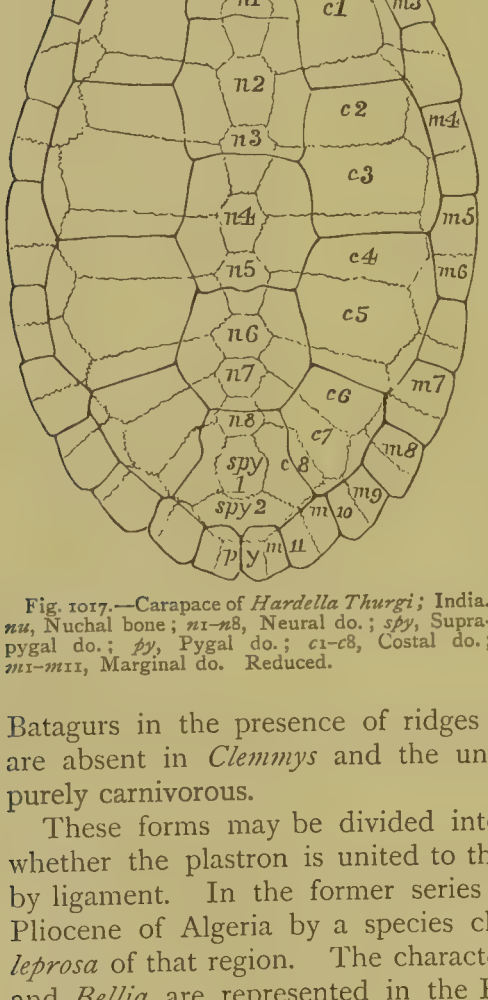


Fig. 1017.—Carapace of *Hardella Thurgi*; India. *nu*, Nuchal bone; *n1–n8*, Neural do.; *spy*, Suprapygal do.; *py*, Pygal do.; *c1–c8*, Costal do.; *m1–m11*, Marginal do. Reduced.

These forms may be divided into two groups, according as to whether the plastron is united to the carapace by suture, or simply by ligament. In the former series *Clemmys* is represented in the Pliocene of Algeria by a species closely allied to the existing *C. leprosa* of that region. The characteristic Oriental genera *Damonia* and *Bellia* are represented in the Pliocene Siwaliks of India; the fossil *Damonia* being apparently inseparable from the living *D. Hamiltoni*. In the second series, where there is a more or less complete transverse hinge in the plastron at the junction of the hyo- and hypoplastrals, and the buttresses of the carapace may be wanting, we find remains of the existing *Emys orbicularis* (*E. lutraria* or *Lutremys*), commonly known as the European Pond-tortoise, in the Pleistocene of England and the Continent. *Cistudo*,

which is almost exclusively terrestrial, has been recorded from the Continental Miocene. The Indian genus *Nicoria*, which is represented by the existing *N.* (*Chaibassia*) *tricarinata* in the Siwaliks, is distinguished from all the preceding forms in that the neural bones have their short side placed posteriorly. The extinct *Ptychogaster*, of the Lower Miocene (Upper Oligocene) of France, is characterised by the ligamentous junction of the hypoplastral with the carapace, and by the presence of a hinge between the hypo- and hyoplastrals, and also by the contour of the neural and costal bones, which approximate to those of the true Tortoises; from which we may assume that this form was mainly of terrestrial habits. In both genera the humero-pectoral sulcus cuts the entoplastral bone.

In the land Tortoises, forming the last group of the family, the neural bones are generally very short and wide, and may be either hexagonal, or alternately tetragonal and octagonal; while the costal bones are generally alternately short and long at their inner and outer extremities; the suture between the marginal and costal bones usually coincides with the sulcus dividing the corresponding shields, and the caudal shield is generally undivided. In most cases the sulcus between the humeral and pectoral shields is behind the entoplastral bone. The digits differ from those of most of the preceding genera by being adapted solely for walking, and devoid of webs; while the metacarpals are shorter, and the humerus is very much curved, with its radial and ulnar processes approximated. The least specialised existing forms are *Cynixis* and *Pyxis*, which have neural bones like those of *Homopus*, but costals of the ordinary Emydine type; they appear to be unknown as fossils. *Hadrianus*, of the Upper (Bridger) Eocene of the United States, includes generalised Tortoises of large size, in which the neural bones are elongated and hexagonal, with the shorter lateral surfaces posterior; the costals do not alternate in length; the vertebral shields are narrow; and the caudal shield is divided. The genus *Homopus*, which now includes a few species of small size confined to Africa, has no ridge on the palate, and the neural bones are short and hexagonal, with short postero-lateral surfaces, and the caudal shield is single. It is represented in the Upper Miocene of Switzerland by the so-called *Emys scutella*, and in the London Clay by *E. Comptoni*. In *Stylemys*, from the White River Miocene of the United States, the short neural bones have their shorter lateral surface placed anteriorly, the posterior costals do not alternate in length at their extremities, and there is a single caudal shield. All the remaining forms may be included in *Testudo*, in which the palate has one or two ridges; the neural bones usually consist of an alternation of small tetragonal and larger octagonal ones; while the anterior extremity of the epiplastrals is more or less thickened. In the skull the pterygoids are wide, and depressed

in the middle (fig. 1017 *bis*). Usually the caudal shield is single, but it may be divided. The ribs have no heads for articulation with the vertebræ. The forms described as *Manuria* and *Colossochelys* may be included in this genus, which comprises a large number of species. Exclusive of the Jurassic so-called *T. Stricklandi*, which has been already mentioned under the head of *Protochelys*, the earliest occurrence of the genus appears to be in the Upper Eocene Phosphorites of France; it is, however, not certain that the form from these deposits may not be referable to one of the American genera. A marginal in the British Museum indicates an individual about 30 inches in length. *T. gigas*, of the Miocene of Haute-Loire, is a still larger form; and species of large dimensions also occur in the Lower Miocene of Allier and the Middle Miocene of Gers, as well as in the Pliocene of France and Greece.

The huge *T.* (*Colossochelys*) *atlas*, of the Pliocene Siwaliks of India, was one of the earliest of the large extinct forms brought to the notice of science, although its size has been greatly exaggerated. It appears, indeed, that the length of the carapace was about six feet, or one-third greater than in *T. elephantina*, of the Galapagos Islands. This species is remarkable for the great development of the epiplastral bones, which formed a pair of horn-like processes; and is also noteworthy for the anchylosis of the three bones of the pelvis into an innominate bone. The skull, which probably belongs to this species, resembles in structure the skulls of the recent giant tortoises of Aldabra. The carapace had no nuchal shield, the caudal shield was divided, and the limbs were covered with bony ossicles, as in the existing *T. emys* of India, to which this form was probably allied. The large *T. perpiniana*, of the Pliocene of France, in which the depressed carapace measures nearly four feet in length, and the limbs were likewise covered with dermal ossicles, was probably also nearly allied. An unnamed species, from the Pliocene of the Siwalik Hills, has a skull resembling that of the Galapagos tortoises (fig. 1017 *bis*); which are characterised by the backward extension of the opisthotics. We also find in the Siwaliks *T. Cautleyi* characterised by its small epiplastrals; and *T. punjabiensis*, which appears to have been a form allied to the smaller existing Indian *T. emys*. Remains of giant tortoises also occur in the Pleistocene cave-deposits of Malta.

Finally, we must not omit to briefly mention the giant tortoises of the present epoch, which, it appears, have been driven from the continental areas by the competition of the higher types of life to seek refuge in islands, where they attained an extraordinary numerical development, till their haunts were invaded by man. These tortoises formerly existed in great numbers in the islands of the Aldabra group, lying to the north-west of Madagascar; in the Mascarenes, which comprise Mauritius and Rodriguez; and also in the Galapagos, or "Tortoise-Islands," which lie off the coast of South America. The Aldabra Tortoises are characterised by their deeply excavated palate, short opisthotics, and the presence of a nuchal and of double gular shields. Some of them were living in the year 1877. In the Pleistocene of Madagascar remains of two very large species have been found, both of which present the characters of the Aldabra forms. The Mascarene species have no nuchal shield, and only a single gular; and the whole of them have been exterminated by human

agency. Their skulls resemble those of the next group (fig. 1017 *bis*) in the slight excavation of the palate, and the produced opisthotics. Finally, the Galapagos tortoises, a considerable number of which were found in Albemarle and Abingdon Islands during the voyage of the Challenger, are distinguished by the double gulars and the absence of the nuchal shield. From the Pleistocene of South America, Dr Moreno describes two large tortoises allied to the Galapagos forms; one of them being

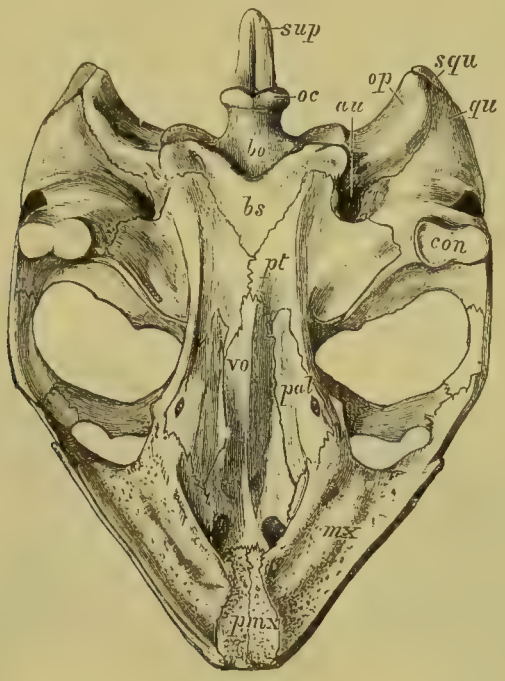


Fig. 1017 *bis*. — Palatal aspect of the cranium of *Testudo microphyes*; from the Galapagos Islands. Two-thirds natural size. *au*, Auditory aperture; *bo*, Basioccipital; *bs*, Basisphenoid; *con*, Condyle of quadrate; *mx*, Maxilla; *oc*, Occipital condyle; *op*, Opisthotic; *pal*, Palatine; *pmx*, Premaxilla; *pt*, Pterygoid; *qu*, Quadrate; *squ*, Squamosal; *sup*, Supraoccipital spine; *vo*, Vomer.

described as the probable ancestor of *T. nigra* (*elephantopus*) of the latter group. The carapace of *T. elephantina* measures four feet in a straight line.

Family Chelonidæ.—The last family of the Cryptodira differs from all the preceding in having the limbs modified into more or less complete paddles or flippers (fig. 1018), which in the existing forms have only one or two claws. The carapace is broad and more or less depressed, and is very generally heart-shaped (fig. 1018), although in some of the early forms it is rounded at both extremities. The nuchal bone has no costiform process; there are usually larger or smaller unossified spaces between the costals and marginals of the carapace (fig. 1006), but in very old individuals these may obliterate in some forms; and the plastron is not articu-

lated to the carapace, and has digitated lateral terminations, and generally a larger or smaller median vacuity (fig. 1009). The humerus is more or less flattened, with the axis of the head generally placed nearly immediately above that of the shaft, and the radial process small, and placed more or less below the well-developed head. The caudal vertebræ are procœlous, and the cervicals extremely short. In the skull the temporal fossæ are completely roofed over by bone, so that the squamosal joins the parietal; and the bones of the palate unite for a longer or shorter distance beneath the narial passage, so as to throw the posterior nares more or less backward (fig. 1020). The prefrontals (as in most *Testudinidæ*) always form a re-entering angle posteriorly; and the tympanic cavity is quite open posteriorly, so as to expose the stapes. In old individuals the vacuities in the shell tend to ob-

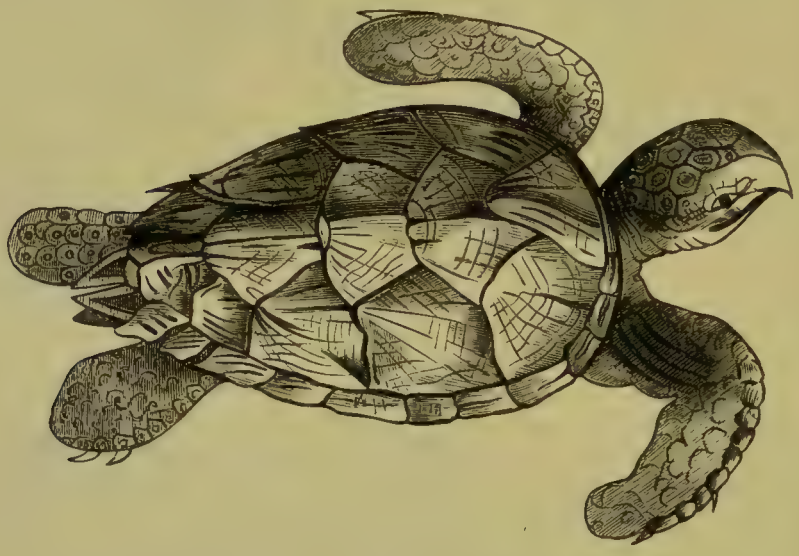


Fig. 1018.—Young of the Hawksbill Turtle (*Chelone imbricata*). Much reduced. (After Bell.)

literate, and in the more generalised extinct types this tendency is much more marked, and it is quite probable that in some cases they may have completely disappeared. This more complete ossification of the shell in these generalised types indicates affinity with the preceding families, and probably more especially with the *Acichelyidæ;* and the same is indicated by other features, such as the more marked constriction of the shaft of the humerus, and the more oblique position of its head, together with the probable presence of claws to all the digits. Some writers, indeed, consider these more generalised types as entitled to constitute a distinct family—the *Propleuridæ;* but their close relationship to the existing Log-

gerhead forbids this view. We have already suggested reasons for regarding this family as being descended from the Mesozoic *Acichelyidæ*, and from this point of view it is interesting to note the presence of an intergular shield in the plastron of the existing, and probably, therefore, of the fossil forms, since, as we have already stated, this appears to be an archaic feature. The same observation will apply to the open tympanic ring. At the present day there are four living species of Turtles — viz., the Loggerhead (*Thalassochelys caretta*, fig. 1006), the Mexican Loggerhead (*T. Kempi*), the Hawksbill (*Chelone imbricata*, fig. 1018), and the Green Turtle (*C. mydas*), all of which are of purely marine habits. The Hawksbill alone is carnivorous; and is further peculiar for the circumstance that in the young state the epidermal shields imbricate, instead of uniting by their edges. It has been suggested that the extinct genera were of estuarine rather than purely marine habits; and this is borne out by their occurrence in the estuarine deposits of the London Clay, to the exclusion of the marine genus *Chelone*.

The most remarkable of the extinct genera is *Lytoloma* (*Euclastes*, *Puppigerus*, *Glossochelys*, or *Erquelinnesia*), which occurs typically in the Eocene of North America and the London Clay, and is also represented in the Middle Eocene of Bracklesham, as well as in the Chalk and Cambridge Greensand. In the typical Eocene forms, like the so-called *Chelone planimentum* and *C. crassicostatum* of the London Clay, the skull is as large in proportion to the shell, as in *Macroclemmys* among the *Chelydridæ*. The skull of the adult is remarkable for the extremely backward position of the posterior nares, which are approximated to the basioccipital; and for the length and width of the mandibular symphysis (fig. 1019, A). The palate has low alveolar walls, and no oral ridge; the nares and orbits are directed somewhat upwardly; and the bar between the latter is narrow. The shell is characterised by the great extent of its ossification, as well as by the rounded posterior extremity of the carapace, and the sutural connection of the broad xiphiplastrals in the median line. The head of the humerus is somewhat oblique, and its shaft much constricted. The limbs were clawed. Curiously enough, in the young, and perhaps also in the adult of some of the smaller forms, the posterior nares were placed much less backwardly, and the mandibular symphysis was shorter and less flattened. It is probable that at least some of the North American Eocene forms described as *Osteopygis*, *Propleura*, and *Catapleura*, are not separable from this genus; while a turtle from the Cretaceous of Australia, originally described by the preoccupied name of *Notochelys*, but which has been provisionally designated *Notochelone*, is probably also nearly related.

Closely allied to the preceding is the genus *Thalassochelys*, as represented by the Loggerhead (fig. 1006). The skull is, however, relatively smaller in proportion to the shell, which is distinguished by the presence of five costal shields; the carapace is heart-shaped; the xiphiplastrals are narrow, and join only at their extremities; while the terminal phalangeals are flattened and have but one or two claws. The shell is distinguished from that of *Chelone* by its more complete ossification, and its T-shaped entoplastral; while



Fig. 1019.—Oral aspect of the left half of the mandible of *Lytoloma crassicostatum* (A), and *Chelone mydas* (B). Reduced. The former from the Lower Eocene of Belgium, the latter recent. *c*, Postarticular process; *o*, Splenial; *n*, Geniohyoid groove; *g*, *k*, Insertion of temporal muscle; *h*, Coronoid process.

the humerus is more constricted, and has its head placed more obliquely. The position of the posterior nares and the form of the palatal walls and mandibular symphysis closely resemble the same parts in the young of *Lytoloma*. In very old specimens the vacuities between the costals and marginals completely close up. This genus probably occurs in the London Clay,[1] and also in the Middle Eocene of Bracklesham.

[1] As indicated by a mandibular symphysis in the British Museum.

In *Argillochelys*, of the London Clay, the skull (fig. 1020), which is very short and has deeply emarginate pterygoids, differs from that of the preceding genera by the presence of an oral ridge on either side of the palate and in the middle of the mandibular symphysis, although these are present in the Mexican Loggerhead. The vomer, as in the young of *Lytoloma*, is very long, and extends forwards to join the premaxillæ; and the pterygoids are characterised by the forward position of their ectopterygoid processes. The shell seems to have been much like that of *Thalassochelys*, but had only four costal shields, and its plastron was perhaps

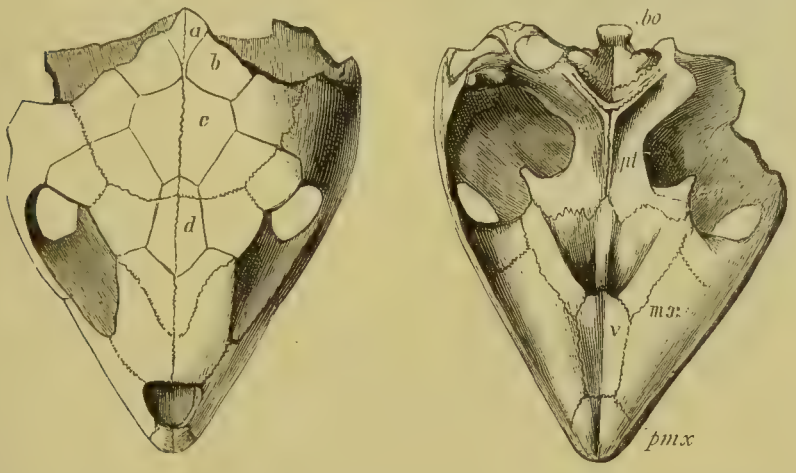


Fig. 1020.—Frontal and palatal aspects of a young cranium of *Argillochelys cuneiceps;* from the London Clay. Owing to immaturity the palatal ridges are imperfectly developed. *a*, Occipital, *b*, Paroccipital, *c*, Parietal, and *d*, Frontal epidermal shields; *bo*, Basioccipital; *pt*, Pterygoid; *ept*, Ectopterygoid process of do.; *v*, Vomer; *mx*, Maxilla; *pmx*, Premaxilla. The bones on the frontal aspect correspond with those of fig. 1022, in which letters are given.

less ossified, although the xiphiplastrals united extensively in the middle line. The mandibular symphysis is convex, and comparatively short. The skull of the type species was originally described as *Chelone cuneiceps;* while the shells figured as *C. subcristata* and *C. convexa* are referable to this genus.

In the typical genus *Chelone* the skull is much smaller in proportion to the shell than in *Thalassochelys*. It is characterised by the more or less nearly vertical position of the nares and orbits, and the width of the bar between the latter; by the tall alveolar walls and the oral ridges of the palate and mandibular symphysis; the long pterygoids, with the ectopterygoid processes placed somewhat backwardly; the forward position of the posterior nares; and the more or less marked shortness of the convex mandibular symphysis (fig. 1019, B). The skull, moreover, has no occipital epidermal shield, which is generally present in the other forms (fig. 1020). In the

shell the carapace is either heart-shaped, or pointed at each end (fig. 1021); the vacuities are large and persistent; the entoplastral is long and dagger-shaped; and the xiphiplastrals are slender and separate (fig. 1009). The humerus is but little constricted, with its head nearly on the axis of the shaft; and the coracoid is longer and more slender than in *Thalassochelys*; the Green Turtle (*C. mydas*) being more specialised in these respects than the Hawksbill (fig. 1018). The earliest occurrence of the genus appears to be in the Cambridge Greensand and Gault, where *C. Jessoni* has a very massive mandible, somewhat resembling that of the Hawksbill. This form may possibly be identical with *C. Benstedi* of the Chalk (fig. 1021), which is only definitely known by very young shells, and has been made the type of the genus *Cimoliochelys*. In the topmost Cretaceous of Maastricht the gigantic *C. Hoffmanni* appears to be allied to *C. imbricata*, but has a shorter and wider palate and mandibular symphysis, a more deeply emarginate nuchal, and the costal bones extremely short. From the latter very specialised character Dr Baur regards this species as entitled to generic distinction, and has proposed the name of *Allopleuron*. An equally large, and perhaps closely allied turtle occurs in the English Chalk. In the higher Miocene of Bordeaux *C. girondica* appears to be a form closely allied to existing types.

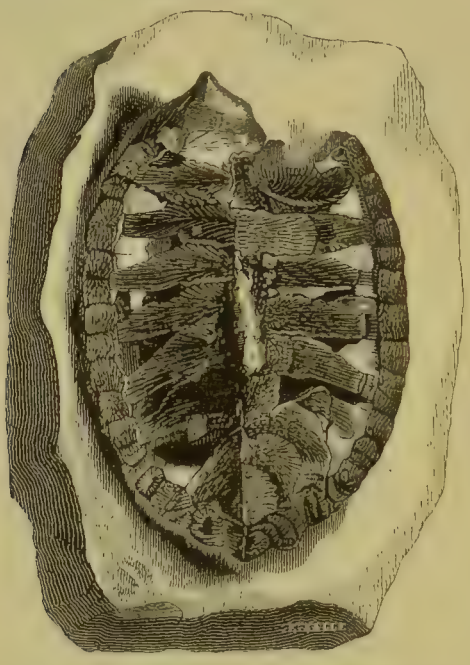


Fig. 1021.—Carapace of *Chelone* (?) *Benstedi*; from the English Chalk. Reduced. (After Owen.)

Section 4. Trionychoidea.—The last section of the suborder includes the mud-turtles or soft-tortoises, of the freshwaters of Asia, Africa, and North America; all of which are of aquatic and carnivorous habits. These forms, which may probably be regarded as extremely specialised types, present the following distinctive features. The shell is sculptured and devoid of epidermal shields; its entoplastral being in the form of a chevron, which divides the epiplastral from the hyoplastral; and the marginals, if present, forming only an incomplete series at the posterior extremity of the carapace, and having no connection with the ribs. The long cer-

vical vertebræ have no distinct transverse processes, and the eighth articulates with the first dorsal solely by the zygapophyses, thus forming the most remarkably complete hinge-joint among the whole of the Vertebrata. The fourth digit in each limb is characterised by having not less than four phalangeals. The form of the tympanic ring of the quadrate, and the relations of the latter to the mandible, are of the same type as in the Cryptodira; and we find a similar absence of union between the pelvis and the plastron. In the cranium (fig. 1022) the chief distinctive features are to be found in the palate; thus the broad pterygoids are separated from one another by the basisphenoid, which extends forwards to join the palatines; the latter, owing to the small size of the vomer, uniting extensively in the middle line; and the whole structure of the palate being of a Pleurodiran type. As minor characters of the skull, attention may be directed to the open temporal fossæ, and the forward position and upward direction of the small orbits, as well as to the extreme development of the backward processes of the supraoccipital and squamosal. The sacral and caudal ribs articulate only with the arches of the vertebræ, and there are no chevrons. The plastron is always entirely separate from the carapace, and has a large median vacuity and digitate extremities, as in the marine *Chelonidæ*. Further, the head and neck are retracted within the carapace after the Cryptodiran manner, but, owing to the peculiar structure of the eighth cervical vertebra, in a still more complete way. In all cases the posterior lateral surfaces of the neural bones of the carapace are much shorter than the anterior.

The marked resemblance of the palate and the general aspect of the Trionychoid skull to that of existing Pleurodira is a circumstance that does not admit of a ready explanation from a phylogenetic point of view, unless we adopt the somewhat improbable suggestion that the Pleurodira gave origin to the Trionychoidea at a time when their pterygoids had attained their full width, but while the tympanic ring was still partially open.

Family Trionychidæ.—The whole of the members of this section may be included in a single family, which is, however, susceptible of division into two subfamilies. In the first, or *Emydinæ*, the opisthotic of the skull unites with the pterygoid to divide the posterior aperture of the auditory labyrinth into two foramina; the hyo- and hypoplastral of either side are fused together; the sculpture of the carapace is tuberculated; and marginals may be present. The existing Oriental genus *Emyda*, in which marginals and a complete series of neurals are present, is represented by numerous species in the Pliocene Siwaliks of India, some of which attained very large dimensions. The African genera *Cyclanorbis* and *Cycloderma*, in which marginals were not developed, are at present unknown in a

fossil state. In the second subfamily, or *Trionychinæ*, the hyo- and hypoplastrals remain distinct throughout life; the pterygoid does not join the opisthotic behind the labyrinth; the sculpture usually consists of sinuous ridges or pits; and marginal bones are never developed in the carapace. The type genus *Trionyx* is widely distributed at the present day, and extends downwards into the Lower Eocene of both Europe and the United States, and is also represented in the Upper Cretaceous of the latter area. Many species are remarkable for showing dimorphic types of skull, which in one modification has a broad palate adapted for crushing, while in the other the palate is very narrow. The Indian species, in which the skulls are not subject to this variation, have two short neural bones between the first costals; while in the recent American forms there are but seven pairs of costals. All the European fossil forms agree with the majority of species in having only one long neural bone between the first costals. In Europe this genus appears to be unknown above the Upper Miocene of Œningen, and it is extremely abundant in the Upper Eocene (Lower Oligocene) of Hordwell. The existing Indian species occur in the Pleistocene and Pliocene of that country. Of the American Tertiary species at least some have eight costals, and in some cases only six neurals. The Lower Eocene and Upper Cretaceous forms described by Professor Cope as *Plastomenus* may be included in the type genus, since the thickening of the plastron can scarcely be regarded as a generic character. The same remark applies to the Eocene *Axestus*, of the United States, in which the plastron is smooth, as in some existing forms. An apparently distinct type, in which the outer margin of the costals is deeply grooved, occurs, however, in the English Upper Eocene, which has been named *Aulacochelys*. Finally, the exclusively Oriental genus *Chitra* is represented in the Pliocene and Pleistocene of India by remains of the one existing species *C. indica*, the largest member of the family.

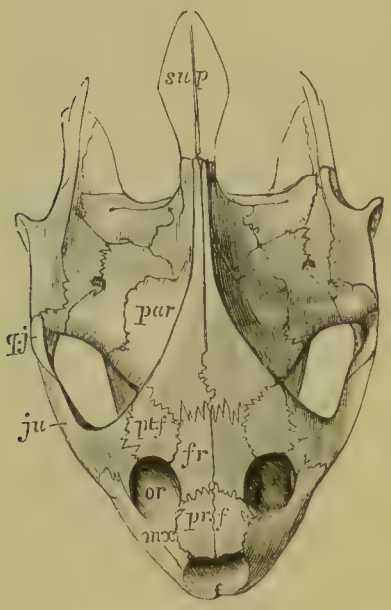


Fig. 1022.—Frontal aspect of the cranium of *Trionyx gangeticus*; from the Pleistocene of India. Reduced. *sup*, Supraoccipital; *par*, Parietal; *pt.f*, Postfrontal; *fr*, Frontal; *prf*, Prefrontal + nasal; *mx*, Maxilla; *ju*, Jugal; *q.j*, Quadratojugal; *or*, Orbit. The processes on either side of the supraoccipital are formed externally by the squamosal, and internally by the opisthotic, of which the inner border articulates with the supraoccipital; externally to the parietal is the proötic.

CHAPTER LIV.

CLASS REPTILIA — continued.

Orders Ichthyopterygia, Proterosauria, Rhynchocephalia, and Squamata.

Streptostylic Branch. — According to the arrangement proposed by Dr Baur, this branch is taken to include the four orders mentioned in the heading of this chapter. These orders present a remarkable instance of the divergent views obtaining among different writers as to the classification of Reptiles. Thus Professor Cope has proposed to place the Ichthyopterygia in a group by themselves, which he regards as of equal value to another containing all the other orders; while Professor Seeley at one time regarded this order as a division of the Dinosauria, although its relationship to the Squamata had been long before pointed out by Sir R. Owen. Professor Seeley has also proposed to separate the Squamata from all other Reptiles under the name of Cœnosauria, and to include the Rhynchocephalia in a second division as Palæosauria. Professor Cope, while not going so far as this, places the Rhynchocephalia in the Synaptosaurian branch; while Professor Huxley would include both that group and the Proterosauria in the Squamata (Lacertilia), from which the Ophidia are excluded. Dr Baur, again, merges the Proterosauria in the Rhynchocephalia, and regards the latter as a distinct order allied to the Squamata. This middle course is followed in the present work, although the Proterosauria, in accordance with the views of Professor Seeley, are provisionally allowed to rank as an order.

The present branch may be collectively characterised as follows: The dentition is very generally either acrodont or pleurodont, with the teeth of the adult anchylosed to the jaws; but the teeth may be implanted in a groove, and remain free. In addition to their presence in the jaws, teeth may also be developed on the palatine and pterygoid, and very rarely on the vomer. There is very fre-

quently a parietal foramen; the superior temporal arcade is generally present, but in the more specialised forms the inferior is often wanting. The quadrate may be either movably or immovably attached by its proximal extremity to the cranium; a columella is very generally present; and the ramus of the mandible never has a lateral vacuity. The precoracoid appears to be fused with the coracoid, and may be represented by a precoracoidal process (fig. 1040), or its position indicated merely by a fontanelle, while in the Ichthyopterygia even the latter is wanting. A T-shaped interclavicle and clavicles are present in all the earlier and a large proportion of the later forms. Usually all, or nearly all, of the dorsal ribs articulate by single heads; the dorsal vertebræ either have short or rudimental transverse processes, which are never placed entirely on the arch, or (Ichthyopterygia) a pair of facets on the centrum; and, with one exception, there are not more than two vertebræ in the sacrum. Abdominal ribs are present in the earlier, but are lost in most of the later forms. The humerus frequently has an ectepicondylar foramen. The number of phalangeals in the digits of pentedactylate land forms is generally 2, 3, 4, 5, 3, in the manus, and 2, 3, 4, 5, 4 in the pes.

In no case are secondary posterior nares formed by the development of plates from the bones of the palate to floor the narial passage; the posterior nares consequently always forming more or less slit-like horizontal apertures in the roof of the mouth. Neither is the posterior extremity of the palate ever completely closed by the junction of the pterygoids with the basisphenoid, after the fashion obtaining in the Chelonia (fig. 1017 *bis*) and some Sauropterygia; there being always a vacuity between the hinder extremities of the pterygoids which displays the presphenoidal rostrum.

Order IV. Ichthyopterygia.—The Mesozoic Ichthyosaurs and their allies were large marine Reptiles, with the body long, and shaped somewhat like that of the Cetacea (fig. 1023), without



Fig. 1023.—Greatly reduced restoration of the skeleton of *Ichthyosaurus communis*; from the Lower Lias of Dorsetshire. The pelvic limb is relatively too large. (After Owen.)

either dermal or epidermal skeleton; the limbs being modified into paddles, in which the component bones were in apposition on all sides, and the phalangeals were oval or polygonal, and increased beyond the normal number. The skull (fig. 1024) has the facial region produced into a long rostrum, mainly formed by the pre-

maxillæ in the upper jaw; and the nares are consequently approximated to the orbit, which is of very large size, and has a ring of bony plates in the sclerotic; there is a large parietal foramen; and there are two temporal arcades connected together by the supratemporal (prosquamosal or supraquadrate), which roofs over the infratemporal fossa, after the Labyrinthodont fashion. Other char-

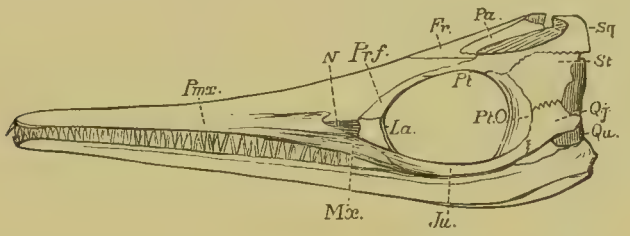


Fig. 1024.—Reduced left lateral view of the skull of *Ichthyosaurus intermedius*; from the Lower Lias of Dorsetshire. *Pmx*, Premaxilla; *Mx*, Maxilla; *N*, Nares; *La*, Lachrymal; *Prf*, Prefrontal; *Fr*, Frontal; *Pa*, Parietal; *Pt*, Postfrontal; *St*, Supratemporal; *Sq*, Squamosal; *Qj*, Quadratojugal; *Qu*, Quadrate; *Ju*, Jugal; *Pt.O*, Postorbital. (After Huxley.)

acteristic features of the skull are the small frontals; the presence of an opisthotic in the occipital region; the distinctness of the postorbital from the postfrontal, and of the lachrymal from the prefrontal; the firm fixture of the quadrate, which does not, however, suturally unite with the pterygoid; and the presence of a foramen separating the middle portion of the quadratojugal from that bone, as



Fig. 1025.—The centrum of an anterior dorsal vertebra of *Ichthyosaurus*, viewed in section, and from the anterior and left lateral aspects; from the Kimeridge Clay of Wiltshire. Reduced. (After Owen.)

in the existing Rhynchocephalian genus *Sphenodon*, and the presence of a columella, or epipterygoid. The palate has essentially the same structure as in the last-named genus. As in the Squamata, there is no lateral vacuity in the mandibular rami. The teeth are confined to the jaws, and are implanted in a continuous groove, without anchylosis to the bone. Their crowns are sharply pointed, and are usually

cylindrical and deeply fluted (fig. 1032), but are occasionally compressed, carinated, and smooth (fig. 1028). The vertebral column is primarily divisible only into a precaudal and a caudal series, there being no sacrum. The centra (fig. 1025) are amphicœlous, more or less disk-like; and either deeply cupped or nearly flat. On either side those of the precaudal series (fig. 1025) carry a pair of tubercles for the articulation of the double-headed ribs; while in the caudal region these tubercles coalesce. Superiorly each centrum has a pair of flattened surfaces for the attachment of the neural arches, which are united merely by synchondrosis. In the cervical region the tubercles for the ribs are placed near the summit of the lateral surfaces of the centra, and they gradually descend on the centrum, till they reach the base of the lateral surface in the posterior precaudal and caudal regions. In some forms the upper costal tubercle of the anterior vertebræ is placed either partly or entirely on the neural arch, and it is convenient to term such vertebræ, or their homologues, cervicals, and the remainder of the precaudal series dorsals. The centrum of the atlas vertebra is well developed, and

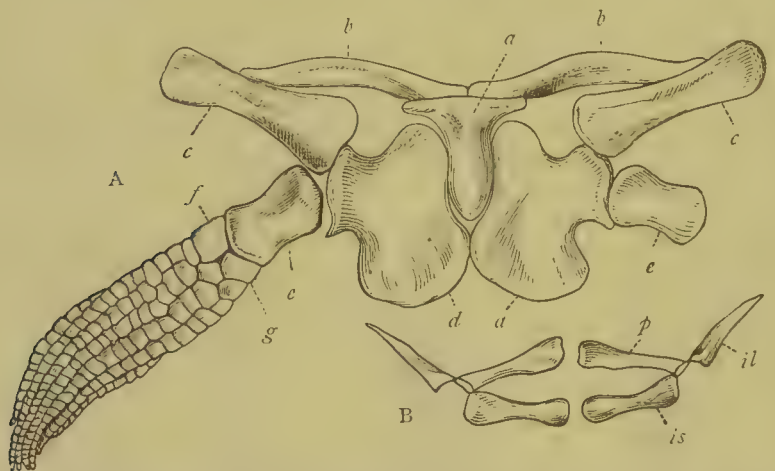


Fig. 1026.—A, Ventral aspect of the pectoral girdle and right limb of *Ichthyosaurus intermedius*. B, Pelvic girdle of do. Reduced. *a*, Interclavicle; *b*, Clavicle; *c*, Scapula; *d*, Coracoid; *e*, Humerus; *f*, Ulna; *g*, Radius; *il*, Ilium; *is*, Ischium; *p*, Pubis. (After Huxley.)

there is a large intercentum between the atlas and the skull, and another between the former and the axis. There was no sternum; but a complex system of abdominal ribs was developed. The dorsal ribs were devoid of uncinate processes; and ribs occur in the caudal region. In the pectoral girdle (fig. 1026, A) there is no precoracoid; but clavicles and a T-shaped interclavicle, like the corresponding bones of the Lacertilia, were developed. The coracoids were large and expanded, devoid of any fontanelle, and not

overlapping one another at their junction. The three bones of the pelvis (fig. 1026, B) are weak and rod-like; the ilia have no connection with the sacral region of the vertebral column; and although the pubis and ischium of opposite sides meet in the middle line, those of the same side do not unite to enclose the obturator notch. The humerus and femur are relatively short; but the radius and tibia are still shorter, and may be reduced to oblong bones in which the transverse diameter is the longer. The humerus has no foramen. The structure of the paddles will be noticed under the head of the different genera; but it may be observed that when there is a difference in the size of the limbs it is the pectoral that is the larger. From the less specialised structure of the limbs of the earlier forms Dr Baur regards the Ichthyopterygia as descendants of land animals; a conclusion which is supported by the argument that had these Reptiles originated directly from Fishes, as was formerly supposed to be the case, they would have retained their gills. In regarding this order as closely allied to *Sphenodon*, Dr Baur lays stress upon the general similarity in the cranial structure, and especially the presence of the foramen between the quadrate and quadratojugal; the identical structure of the abdominal ribs; and the remarkable similarity of the pectoral girdle, which, this author remarks, is only comparable to that of the existing genus, especially when young. In the skull and vertebral column the Ichthyopterygia retain evidences of their Labyrinthodont descent, which are lost in the other orders of this branch.



Fig. 1026 *bis*. — Proximal, dorsal, and distal aspects of the left humerus of *Ichthyosaurus;* from the Kimeridge Clay. One-third natural size. *a*, Trochanteric ridge; *r*, Facet for radius; *u*, Do. for ulna.

This order is known to range with certainty from the Upper Trias to the Upper Chalk. It was also widely distributed in space; its remains having been discovered in the Arctic regions, in Europe, India, Ceram, North America, the east coast of Africa, Australia, and New Zealand. Part of a jaw referred to *Ichthyosaurus* has been described from Malta, which, it has been suggested, may be of Miocene age, but this requires confirmation.

It may be remarked that the humerus and femur of this order are quite unique in that, instead of having convex condyles for the

articulation of the epipodial bones, they present distinct concavities (fig. 1026 *bis*) for their reception.

Family Ichthyosauridæ.—Although Dr Baur makes the genera *Mixosaurus*, *Ichthyosaurus*, and *Opthalmosaurus* the types of as many families, yet it seems on the whole more convenient to include all the known forms in a single family. The most generalised group with which we are at present acquainted is the genus *Mixosaurus*, from the Upper Trias of Italy, which is founded upon a small species presenting the following characters. The humerus and femur articulate distally with two bones; and the radius and ulna are elongated, and separated from one another by an interval throughout their entire length. The teeth are small, and not excessively numerous. It may eventually prove that all the Triassic forms are referable to this genus. The type genus *Ichthyosaurus* is characterised by the usual presence of teeth throughout the jaws; and by the normal articulation of the humerus with only the short radius and ulna, which are in close apposition (fig. 1027). In the pelvic limb the femur similarly articulates only with the tibia and fibula at its distal extremity; and thus this extremity in both the humerus and femur has only two articular facets (fig. 1026 *bis*). The bone which articulates inferiorly with the radius and ulna at their junction is the intermedium (fig. 1027, *i*); while the one filling up the angle between the latter and the radius is the radiale; the opposite angle being occupied by the ulnare. Below the intermedium we have the centrale, which in the more specialised forms may be double (fig. 1031), and below this the remaining carpals, metacarpals, and phalangeals, which are combined to form a pavement-like structure. The bones forming the continuation of the line of the intermedium in fig. 1027 correspond to the middle or third digit of the typical manus; and the structure of this limb indicates that it was derived from a four-fingered ancestor, since the pollex, or first digit, is not represented.

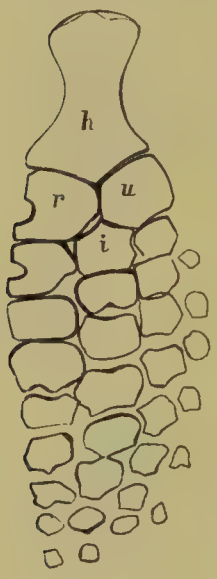


Fig. 1027. — Dorsal aspect of the left pectoral limb of *Ichthyosaurus latifrons*; from the Lower Lias. Reduced. *h*, Humerus; *r*, Radius; *u*, Ulna; *i*, Intermedium. (After Owen.)

Specimens have been obtained from the Lias of Würtemberg and Barrow-on-Soar, in Leicestershire, which show the contour of the integuments of the paddles. It appears from these that on the anterior border of the paddle (fig. 1027 *bis*) there was a comparatively narrow band of integument, which was covered by minute horny scales: while on the posterior border there was a much broader flap, which appears

to have contained parallel bands of muscles set obliquely to the axis of the paddle. In the Latipinnate group (fig. 1027 *bis*) the posterior flap of integument was narrow in proportion to the bony framework of the paddle, and it was produced inferiorly into a long point below the distal bones. In the Longipinnate group, however, the integuments were much wider in proportion to the bones, and they terminated inferiorly in a blunt extremity, which only reached a short distance below the distal bones.

The larger forms attained a length of from thirty to forty feet; and it is thought probable that the extremity of the tail was provided with a membranous fin. All the species were carnivorous; and, as we learn

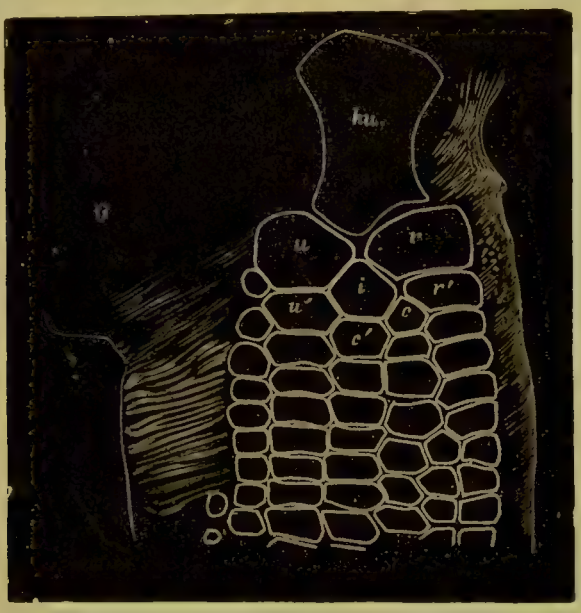


Fig. 1027 *bis*.—Part of the left pectoral limb of *Ichthyosaurus intermedius*, viewed from the ventral aspect, and showing the contour of the integument. One-half natural size. *hu*, Humerus; *r*, Radius; *u*, Ulna; *r'*, Radiale; *i*, Intermedium; *u'*, Ulnare; *c*, *c'*, Centralia. From the Lower Lias of Barrow-on-Soar.

from the so-called coprolites, their food consisted to a considerable extent of Ganoid Fishes. These coprolites further tell us that the intestine was provided with a spiral valve, as in the Selachian fishes. Perhaps, however, the most remarkable circumstance connected with their internal economy is the not unfrequent occurrence of entire skeletons of small individuals within the thoracic and abdominal cavity of larger ones; these small specimens being invariably uninjured, and belonging to the same species as the one in which they are contained. This leads Professor Seeley to conclude that some species or individuals were viviparous, and that the young were probably produced of different relative bulk in different species. There is also evidence to show that in some cases many young were produced at a birth; the number being perhaps a specific character. It cannot, however, be taken as proved that all Ichthyosaurs were viviparous, since in such other Sauropsida and Ichthyopsida in which the same mode of development occurs, it is not distinctive of any entire group; and it is noteworthy that the three specimens

with young figured by Professor Seeley all belong to a single species. This genus may be divided into two groups from the structure of the pectoral limb. In the *Longipinnate*, or least specialised group, which is unknown above the Lias, the orbit is generally of very large dimensions. The pectoral limb (fig. 1027) is characterised by having the third digit, or that arising from the intermedium, comprising only a single longitudinal row of bones, and consequently having only one centrale; while there are usually only four longitudinal rows of phalangeals in this limb, and the radius is nearly square, with a distinct notch in its anterior border (fig. 1027). This group may be further subdivided into minor groups. One of the most aberrant forms is the huge *I. platyodon*, of the Lower Lias, which attained a length of nearly forty feet. This species is characterised by the pelvic paddles being nearly as large as the pectoral; but still more readily by the teeth (fig. 1028), which have compressed, carinated, and smooth crowns, and the roots covered with a coating of cement. *I. lonchiodon* is an allied Lower Liassic form with cylindrical and fluted teeth. Another type is indicated by *I. tenuirostris* and *I. latifrons* (*longirostris*), in which the cranial rostrum (fig. 1029) is greatly elongated and very slender. The paddles (fig. 1027) are remarkable for the large size of the component bones; and in *I. tenuirostris* there is a small circular vacuity between the radius and ulna, indicating the last remnant of the large vacuity found in *Mixosaurus*. Lastly, *I. acutirostris*, *I. zetlandicus*, and *I. integer* are three Upper Liassic members of this group indicating a transition to the next group; the radius of the latter species having no anterior notch. The skull of *I. zetlandicus* is shown in fig. 1030.



Fig. 1028.—Lateral and profile views of a tooth of *Ichthyosaurus platyodon*; from the Lower Lias of Dorsetshire.

In the more specialised or *Latipinnate* group, which ranges from the

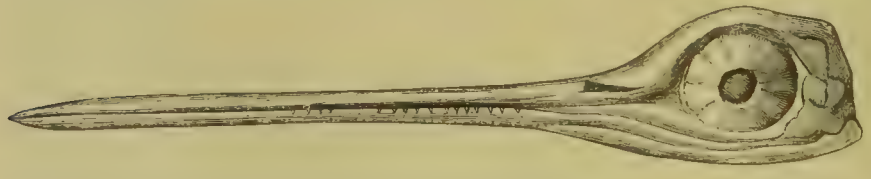


Fig. 1029.—Left lateral view of the skull of *Ichthyosaurus latifrons*; from the Lower Lias of Leicestershire. Reduced.

Lias to the Chalk, the orbit is usually relatively smaller than in the last group. The pectoral limb (fig. 1031) has the third digit, or that arising from the intermedium, with a double longitudinal row of bones, and there are consequently two centralia. There are, moreover, never less than

five longitudinal rows of phalangeals in this limb (the marginal rows are wanting in fig. 1031); and the radius is transversely elongated (and thus very widely removed from the normal type) with an entire anterior border. It is important to observe that in this group the splitting of the third digit and the two centralia are evidently acquired, and not inherited characters. Like the last, this group may be divided into subgroups. In the typical subgroup, which is confined to the Lias, the teeth (fig. 1032) have their roots strongly fluted, and the dorsal aspect of the humerus has no strongly-marked trochanteric ridge. *I.*

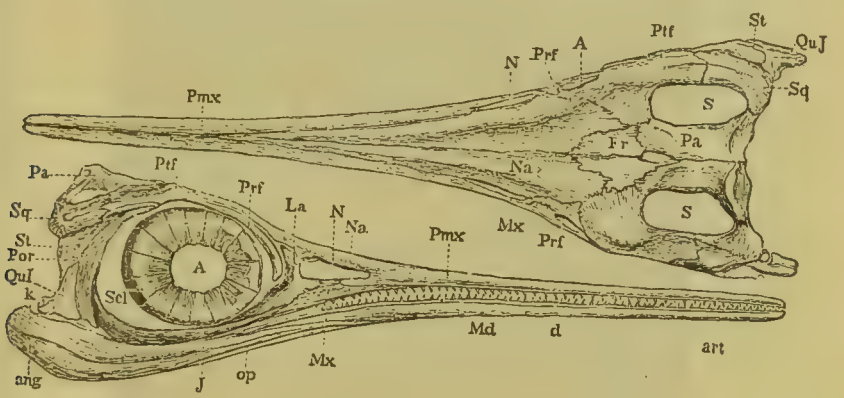


Fig. 1030.—Superior and right lateral aspects of the skull of *Ichthyosaurus zetlandicus*; from the Upper Lias of Caen. Reduced. *Pmx*, Premaxilla; *Mx*, Maxilla; *N*, Nares; *Na*, Nasal; *La*, Lachrymal; *Prf*, Prefrontal; *Fr*, Frontal; *Pa*, Parietal; *Ptf*, Postfrontal; *Sq*, Squamosal; *St*, Supratemporal; *Por*, Postorbital; *QuJ*, Quadratojugal; *J*, Jugal; *A*, Orbit; *S*, Supratemporal fossa; *Scl*, Sclerotic plates; *Md*, Mandible; *k*, Articular; *ang*, Angular; *op*, Splenial; *d*, Dentary. (After Zittel.)

intermedius is the species least widely removed from the preceding group; while the typical *I. communis* is distinguished by the extreme width of the paddles. In a second subgroup, which ranges from the Oxford Clay to the Chalk, the roots of the teeth are invested with a thick layer of cement; the dorsal aspect of the humerus has a prominent trochanteric ridge; and the coracoid differs from that of the preceding subgroup (fig. 1026) by the absence of a posterior notch. This subgroup comprises *I. trigonus*, and probably other allied forms from the Oxford and Kimeridge Clays; and also the well-known *I. campylodon*, from the Upper Cretaceous of a large portion of Europe, to which *I. indicus*, from the corresponding strata of India, and perhaps also *I. australis*, from the Cretaceous of Australia, are probably closely allied. The former is in some respects even more specialised than the following genera. The species referred to this genus from the Polar regions are considered to be of Triassic age; and a species from Ceram may be from Cretaceous beds. The genus is unknown in America.

The most specialised representatives of the family are the genera *Opthalmosaurus*, from the Oxford and Kimeridge Clay and probably also the Cretaceous of England, and *Baptanodon* (*Sauranodon*), from the Upper Jurassic of North America. In the latter teeth, and even a dental groove, were totally wanting, but in the former small teeth were present. In the former (and probably also the

latter) the humerus (fig. 1033) and femur have a prominent trochanteric ridge, and in both they articulate distally with three distinct bones (figs. 1033-34), which in the pectoral limb are correlated

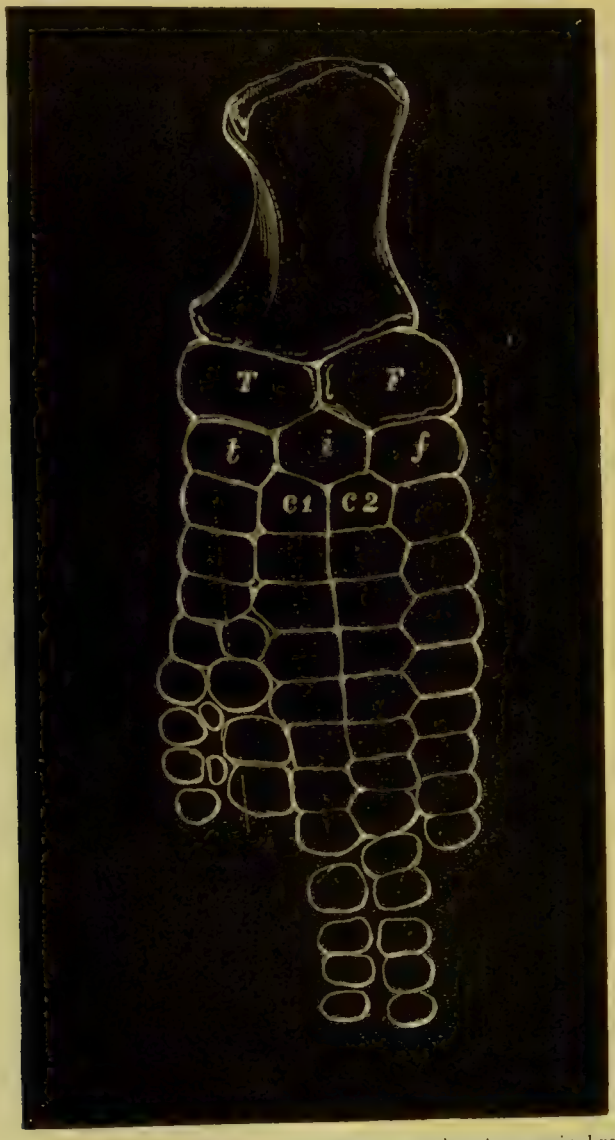


Fig. 1031.—Ventral aspect of the right pectoral limb (wanting the marginal rows) of *Ichthyosaurus intermedius*; from the Lower Lias of Gloucestershire. Reduced. *T*, Radius; *F*, Ulna; *t*, Radiale; *i*, Intermedium; *f*, Ulnare; *c1*, *c2*, Centralia. (After Hawkins and Hulke.)

by Dr Baur with the radius, ulna, and pisiform; the corresponding bones in the pelvic limb (fig. 1034) being the tibia, fibula, and the homologue of the pisiform. The clavicles differ from those of *Ichthyosaurus* in being separate. Both limbs appear to have been

of great width, and the third digit, or the one arising from the intermedium, at least in the American genus, consists of two longitudinal rows of bones. The type species of *Opthalmosaurus* was of moderate size, and occurs in the Oxford and Kimeridge Clays; it is characterised by the inequality in the size of the three distal facets of the humerus. In *O. cantabrigiensis*, of the Cambridge Greensand, which may belong to *Baptanodon*, these three facets have, however, become nearly equal in size; and this form seems therefore to indicate the highest evolution of the order. It should be mentioned that Professor Marsh and Mr Hulke differ from Dr Baur in their interpretation of the three bones of the second segment of the limb of this genus; correlating the middle bone with the intermedium, and the postaxial one with the ulna in the pectoral, and the fibula in the pelvic limb. Finally, it should be observed that a femur, from the Cambridge Greensand, described under the name of *Cetarthrosaurus*, and regarded as belonging to a member of the present order, but which has been referred by Mr Hulke to the suborder Pythono-



Fig. 1032. — Tooth of *Ichthyosaurus communis*; from the Lower Lias of Gloucestershire.

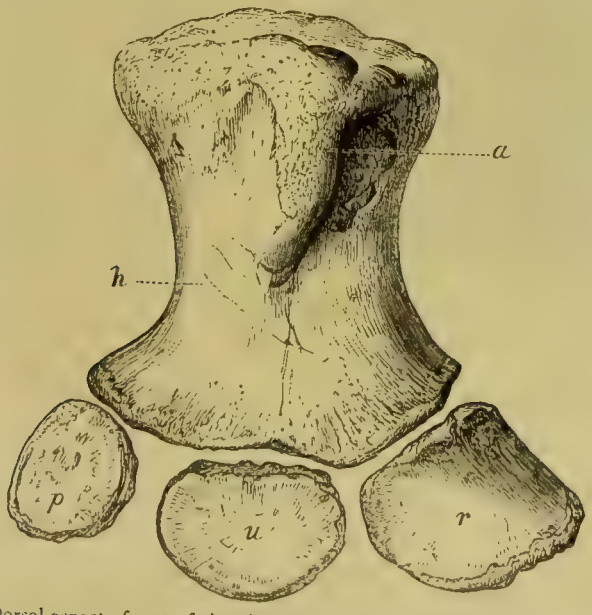


Fig. 1033.—Dorsal aspect of part of the right pectoral limb of *Opthalmosaurus icenicus*; from the Oxford Clay. One-third natural size. *h*, Humerus; *a*, Trochanteric ridge of do.; *r*, Radius; *u*, Ulna; *p*, Pisiform.

morpha of the Squamata, appears to approximate in structure to the femur of *Ichthyosaurus campylodon*, and may therefore really belong to this order.

Order V. Proterosauria.—The genus *Proterosaurus*, from the Middle Permian of Thuringia, is regarded by Professor Seeley as presenting such peculiar features that it is entitled to ordinal distinction, although Dr Baur would include it in the Rhynchocephalia. The skull is very imperfectly known, and although Professor Seeley has attempted its restoration, Professor Credner points out that the specimens scarcely justify the figure. There is some doubt as to the mode of attachment of the teeth to the jaws, but they appear to have been anchylosed to the bone, with cavities beneath them, and were not, as has been supposed, implanted in distinct alveoli. Teeth also occur on the palatine, pterygoid, and vomer; and Professor Seeley considers that the palate was closed. The dorsal vertebræ are amphicœlous, and have no intercentra; but the cervicals appear to have been opisthocœlous, and are remarkable for their length. There were intercentra in the anterior cervical region. In all the vertebræ the arches were anchylosed to the centra; while in the dorsals the costal articulation is placed unusually high. The posterior caudal vertebræ have divided neural spines. Abdominal ribs were fully developed (fig. 1035), and were apparently of the Rhynchocephalian type. It has been suggested that the ilium may have had a preacetabular production; but the pectoral girdle seems to have been of the Rhynchocephalian type, the clavicles and interclavicle, according to Dr Credner, closely resembling those of *Sphenodon*.

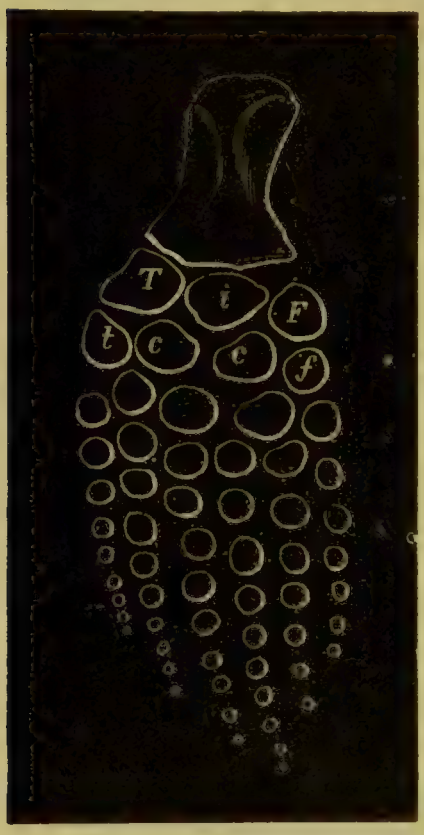


Fig. 1034.—Dorsal aspect of the left pelvic limb of *Baptanodon natans*; from the Upper Jurassic of North America. Reduced. *T*, Tibia; *i*, Fibula; *F*, Bone representing the pisiform of the manus; *t*, Tibiale; *c* (left side), Intermedium; *c* (right side), Fibulare; *f*, Undetermined bone. The two bones beneath the intermedium are the centralia. (After Marsh and Hulke.)

According to Dr Baur there are two centralia in the carpus;

while Professor Seeley describes a centrale (navicular) in the tarsus. The pectoral limb is considerably shorter than the pelvic (left side of fig. 1035); and while both have five digits, neither presents any very strongly marked divergence from the Rhynchocephalian plan of structure. In the type species there were the normal two sacral vertebræ; but according to Professor Seeley, *P. Linki* differs from all other known members of this branch in having three sacrals. It is highly probable that *Proterosaurus* should be regarded as a

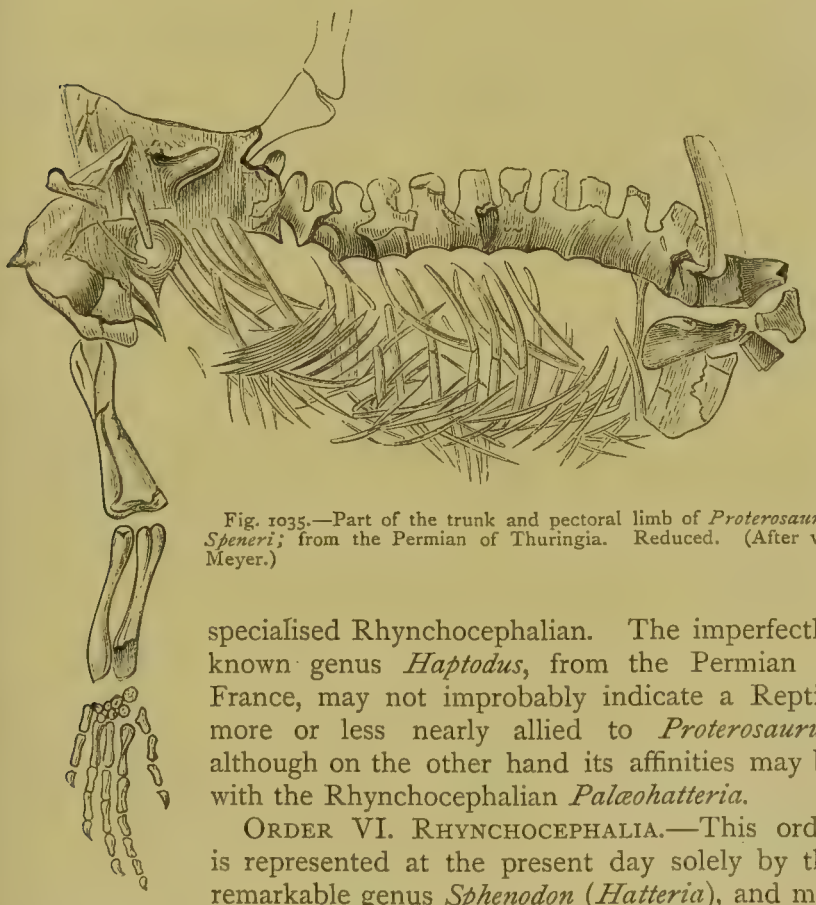


Fig. 1035.—Part of the trunk and pectoral limb of *Proterosaurus Speneri;* from the Permian of Thuringia. Reduced. (After von Meyer.)

specialised Rhynchocephalian. The imperfectly-known genus *Haptodus*, from the Permian of France, may not improbably indicate a Reptile more or less nearly allied to *Proterosaurus*, although on the other hand its affinities may be with the Rhynchocephalian *Palæohatteria*.

Order VI. Rhynchocephalia.—This order is represented at the present day solely by the remarkable genus *Sphenodon* (*Hatteria*), and may be provisionally characterised as follows: The external appearance is usually more or less lizard-like. In the skull the quadrate is immovably fixed by its proximal extremity, and unites by suture with the pterygoid; an inferior temporal arcade is present (fig. 1039); the postorbital, at least in *Sphenodon*, is quite distinct from the postfrontal; the palate is closed anteriorly by the median union of the pterygoids, which, in the living form at least, extend forwards to meet the vomers, and thus separate the

palatines;[1] and the premaxillæ never united. The dentition is usually acrodont. The ribs may have uncinate processes, and abdominal ribs are always developed. The vertebræ may be either opisthocœlous or amphicœlous, and intercentra may be retained.

Dr Baur observes that "the Rhynchocephalia, together with the Proterosauria, to which they are closely allied, are certainly the most generalised group of all Reptiles, and come nearest, in many respects, to that order of Reptiles from which all others took their origin."

This order, if we include *Palæohatteria*, dates from the Permian, but only comparatively few forms are at present known. It may be provisionally divided into three suborders.

Family Palæohatteriidæ.—The genus *Palæohatteria*, of the Permian of Germany, is regarded by Professor Credner, its describer, as so closely allied to the existing *Sphenodon* that it is referred by him to the same family. There can, however, be no question but that it is entitled to be the representative of a distinct family, and probably of a distinct suborder. Dr Baur, with whom Professor Cope is in accord, would even go farther, and remove this genus altogether from the Rhynchocephalia, to place it with *Mesosaurus* in his order Proganosauria. There is, indeed, much to be said in favour of placing both these primitive Reptiles in a single group; but this appears to be outweighed by the resemblance of the one to the true Sauropterygians and of the other to the Rhynchocephalians.

The skull much resembles that of *Sphenodon*, the jugal dividing posteriorly to join the two temporal arcades; but the supra- and infratemporal fossæ are much smaller, while there is a separate lachrymal, and the premaxillæ do not form a beak. Teeth occur not only on the palatines, but also on the vomer and pterygoids, as in the young of *Sphenodon;* and Dr Baur suggests that there was a parasphenoid. There are intercentra between all the vertebræ, in which the neural arches remain distinct from the centra; there are also two sacral vertebræ; and the ribs have no uncinate processes. The teeth of the jaws were acrodont, and anchylosed to the bone. The pectoral girdle presents an approximation, in the form of the clavicles and interclavicle, to that of *Sphenodon;* but the expanded proximal extremities of the clavicles recall the lateral thoracic plates of the Labyrinthodonts, and the coracoid is more like that of the Sauropterygians. This bone, indeed, like the bones of the pelvic girdle, ossifies by radiations from the centre after the manner obtaining in Sauropterygians and Amphibians. The pelvic girdle is widely different from that of *Sphenodon;* the pubes and ischia forming wide flattened plates like those of the Sauropterygian

[1] The same arrangement obtains in the skull of *Nothosaurus*, represented in fig. 991.

genus *Mesosaurus*, and the ischia being almost identical with those of the Amphibia. The tarsus also resembles that of *Mesosaurus* in having five distinct bones in the distal row; while the humerus (as in the latter) has an entepicondylar, or ulnar, foramen.

That *Palæohatteria* is a primitive type connecting the later Rhynchocephalia with the Amphibia there can be no reasonable doubt; and although it presents many points of affinity with *Mesosaurus*, these resemblances are those which we should expect to find in all transitional types, and do not necessarily imply that all the forms in which they occur should be placed in the same group.

Suborder 1. Simædosauria.—This group is represented by the genus *Champsosaurus*, typically from the Lower Eocene of North America, which may be regarded as a somewhat specialised Rhynchocephalian, showing a remarkable affinity, in the general structure of its skull and vertebral column, to *Hyperodapedon*. Dr Baur observes that this genus agrees with the other Rhynchocephalia in the loose condition of the otic bones, and in the nature of the costal articulations; and since it has a fixed quadrate, two temporal arcades, and abdominal ribs, there appears no good reason for its ordinal separation. The adaptation to an aquatic life has, however, necessarily produced considerable structural modifications of secondary import. The correctnèss of these observations has been remarkably shown by the researches of M. Dollo, who finds that the structure of the palate, and the position of the posterior nares, and the general arrangement of the teeth, closely accords with that obtaining in *Hyperodapedon*. The suborder may be characterised as follows: The facial portion of the skull is produced into a long rostrum; the splenial bone enters into the mandibular symphysis; the tail and pelvic limbs are elongated; the vertebræ are amphicœlous; and the ribs have no uncinate processes.

Family Champsosauridæ.—In the type and only known family the nares are single and subterminal; the maxillary and anterior mandibular teeth are large and not fixed to the bone; there is a series of smaller teeth on the palatines and vomers, separated by a groove from those of the maxilla; while there is also an irregular mass of small teeth on the pterygoids, which are completely united in the middle line; the posterior nares form very narrow slits on the sides of the palate; and there is no parietal foramen. There are some twenty-five presacral vertebræ, and the neuro-central suture is persistent. Remains referred to *Champsosaurus* have been found not only in the Lower Eocene of North America, but also in the corresponding horizon of Belgium and Rheims; the latter specimens having been described under the name of *Simædosaurus*. One of the specimens from Rheims indicates an animal of about nine feet in length, but other examples appear to have been of considerably

larger dimensions. The Simædosauria may perhaps be regarded as an offshoot from a stock related to *Hyperodapedon*.

Suborder 2. Sphenodontina.—This group is characterised by the short and more or less triangular skull, in which the premaxillæ are produced into a distinct beak; by the longitudinal series of palatine teeth, separated by a groove (into which the hinder mandibular teeth are received) from those of the maxilla (fig. 1037); and by the presence of uncinate processes to the ribs.

Family Rhynchosauridæ.—This is the most specialised family, and as being most nearly related to *Champsosaurus*, may be noticed first. The nares are single; there are no teeth either in the beak or in the opposing part of the mandible, which were probably cased in horn; there may be more than a single row of palatine teeth; and the presacral vertebræ may be more or less opisthocœlous.

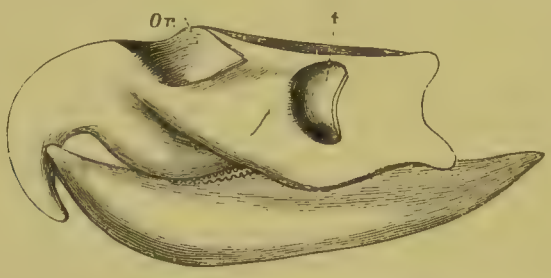


Fig. 1036.—Left lateral view of the skull of *Hyperodapedon Gordoni*, as restored by Professor Huxley; from the Trias of Elgin. Reduced. *Or*, Orbit; *t*, Infratemporal fossa.

The most specialised genus *Hyperodapedon* was originally made known to us by some very imperfect specimens from the Keuper or Upper Trias of Elgin and Warwickshire; but the subsequent discovery of a nearly entire skeleton in the former locality has enabled Professor Huxley to illustrate its full affinities. Remains referred to the same genus also occur in the Maleri stage of the Gondwana system of Central India. The European species attained a length of from six to seven feet, but the Indian form must have been nearly or quite double these dimensions. The skull (fig. 1036) is remarkable for its depressed and triangular form, in which it resembles that of the Chelonian family *Chelydridæ;* and also for the upward direction of the small orbits; the reduced size of the infratemporal fossæ; the strongly-curved and thick premaxillary beak; the diverging clawlike processes of the mandibular symphysis; and the absence of a parietal foramen. Professor Huxley considered that the forked extremities of the mandibular symphysis embraced the premaxillary beak, as is shown in the figure; but later observations indicate that they were received in a pit beneath the beak, which Professor Huxley regarded as containing the apertures of the posterior

nares. The latter probably really formed very small slits on the sides of the palate, as in *Champsosaurus*, and opened between the rows of maxillary and palatine teeth. By far the most remarkable feature is, however, to be found in the upper dentition. On the palatal surface of the peculiar triangular compound bone (fig. 1037), which may be conveniently termed the palato-maxilla, although anteriorly it probably includes the vomer, and posteriorly part of the pterygoid, there are, on the outer or maxillary side, several rows of low pyramidal teeth; then comes the groove for the reception of the edge of the mandible, on the inner side of which there are two or more rows of similar teeth borne by the palatine and vomer, and probably also by the pterygoid. And it is interesting to notice that while in the type species the larger number of rows of teeth occurs on the palatine and vomer, the reverse condition obtains in the Indian form (fig. 1037). In the type species there appears to be no foramen to the humerus, and the presacral vertebræ are slightly opisthocœlous; it is, however, not improbable that the vertebræ of the Indian form were amphicœlous. The extremely solid structure of the palato-maxilla causes this part to be the most frequently preserved; and these bones are very common in the Indian Gondwanas.



Fig. 1037.—Oral surface of the right palato-maxilla of *Hyperodapedon Huxleyi*; from the Maleri stage of Central India. (After Medlicott and Blanford.)

Professor Huxley observes that it is very interesting to note that this suborder had attained its greatest degree of specialisation as early as the Trias; *Hyperodapedon* being in all respects a more modified form than *Sphenodon*. It appears therefore to be probable that in the Permian, or perhaps still earlier, there must have existed Lizards differing less from the existing genus than either *Hyperodapedon* or *Rhynchosaurus*.

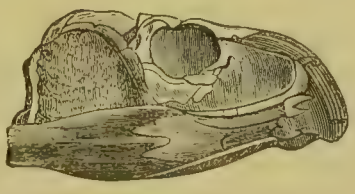


Fig. 1038.—Right lateral aspect of the skull of *Rhynchosaurus articeps*; from the Trias of Warwickshire. Reduced. (After Owen.)

In the typical genus *Rhynchosaurus*, from the English Keuper, of which the type skull is represented in fig. 1038, there is but a single row of palatine teeth; the orbit is large and lateral; the infratemporal fossa of considerable size; and the premaxillary beak long and slender, its form being not

correctly shown in the figure of the type skull. The single described species indicates an animal about three feet in length. This genus serves in some respects to connect *Hyperodapedon* with *Sphenodon*.

Family Sphenodontidæ.—The least specialised family of this suborder is solely known by the existing New Zealand genus *Sphenodon* (*Hatteria*), of which the cranium is shown in fig. 1039. According to Professor Huxley's definition, this genus is characterised by the divided nares; the presence of a single tooth on either side of the premaxillary beak, which was not sheathed in horn; by the single row of palatine teeth; and the amphicœlous vertebræ. In the palate the pterygoids unite anteriorly with the vomer to exclude the palatines from the median line. Additional distinctive features are found in the presence of intercentra between all the vertebræ; in the large size and the lateral position of the orbits; the well-developed parietal foramen; and the large size of the supra- and infratemporal fossæ (fig. 1039). The humerus is remarkable as having both an entepicondylar and an ectepicondylar foramen.

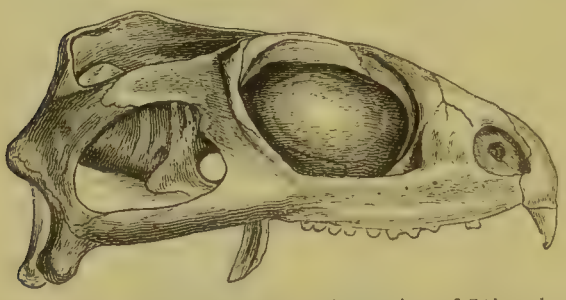


Fig. 1039.—Right lateral view of the cranium of *Sphenodon punctatus*, of New Zealand. (After Günther.)

The Tuataras, as these lizards are called by the Maories, are medium-sized reptiles of extreme rarity, and with nocturnal habits. The alveolar border of the dentary bone of the mandible is received in the groove between the palatine and maxillary teeth, and in old individuals becomes as hard and polished as the teeth themselves, of which it eventually discharges the functions.

Suborder 3. Homæosauria.—This group includes several genera of Mesozoic Reptiles, in which the premaxillæ did not apparently form a beak, and the ribs were devoid of uncinate processes. The dentition is acrodont; but the nature of the palatal dentition is unknown. The vertebræ are amphicœlous, and Dr Baur considers that intercentra were present.

Family Homæosauridæ.—The type family is definitely known from the Kimeridgian Lithographic slates of the Continent, and is characterised as follows. The body is shaped like that of ordinary Lizards; the skull is comparatively broad and short, with oval nares, and a complete postorbital bar; there are no tusk-like teeth in the premaxillæ or mandible; and the pes is of normal structure. The

Kimeridgian genera are *Homæosaurus*, *Ardeosaurus*, and *Sapheosaurus*; all of which are represented by species of small or medium size. The imperfectly known *Aphelosaurus*, from the Permian of France, was regarded by the late Professor Gervais as allied, but it may indicate a distinct family, which does not belong to this group; the number of phalangeals is the same as in existing Lizards.

Family Pleurosauridæ.—This family is typically represented by *Pleurosaurus*, of the Kimeridgian of Bavaria, which is a medium-sized Lizard characterised by the extreme elongation of the body (in which there are a great number of presacral vertebræ), and the long narrow skull, with slit-like nares. *Anguisaurus* and *Acrosaurus*, of the same deposits, belong to this family; but it does not appear certain that they are really distinct from the type genus.

Family Telerpetidæ.—The small *Telerpeton*, of the Upper Trias of Elgin, differs from the *Homæosauridæ* by the presence of tusk-like teeth at the extremities of both jaws, and the reduction in the number of the phalangeals of the fifth digit of the pes to two; in addition to which Professor Huxley considers that the skull had no postorbital bar. The one species is of small size; and although the genus agrees with the *Homæosauridæ* in its acrodont dentition, its serial position must be regarded as provisional. *Saurosternum*, from the Karoo system of South Africa, is not improbably an allied genus; although it has been referred by Sir R. Owen to the Amphibian Labyrinthodonts under the name of *Batrachosaurus*.

Finally, it should be mentioned that Professor Cope includes in the present order the genera *Typothorax* and *Aëtosaurus*, which are here provisionally placed, on the authority of Dr Baur, among the Crocodilia.

Order VII. Squamata.—With this order we come to the consideration of the one represented most numerously at the present day, and containing the true Lizards, the Chamæleons, the extinct Mosasaurians, and the Serpents. In this order the body may be either short, with well-developed limbs and distinct tail (lacertiform); or it may be extremely elongated, without any external trace of limbs, and passing gradually into the tail. As a rule, the whole body and limbs are covered with overlapping horny scales; and these may be underlain by an armour of bony dermal scutes. The limbs may be adapted either for walking on land, or modified into paddles for swimming. In the skull the proximal end of the quadrate is more or less movably articulated; the lower temporal arcade is wanting; the postorbital is generally fused with the postfrontal; the palate is more or less open, the pterygoids being nearly always separated by an interval from one another; and the premaxillæ are

frequently united. The vertebræ are generally procœlous, although rarely amphicœlous; their neurocentral suture is always obliterated; zygosphenal articulations may or may not be present; and intercentra are always wanting. The dorsal ribs never have uncinate processes; and true abdominal ribs are likewise never developed. The carpus has but a single centrale; and the precoracoidal process (fig. 1040) is often well marked.

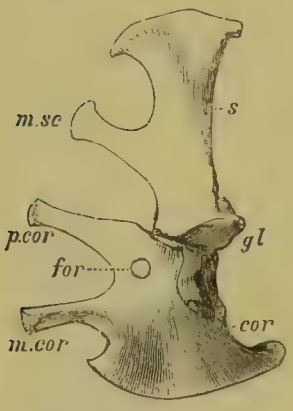


Fig. 1040. — Part of the left pectoral girdle of *Iguana*. *s*, Scapula; *m.sc*, Mesoscapula; *cor*, Coracoid; *p.cor*, Precoracoid; *m.cor*, Mesocoracoid; *for*, Foramen; *gl*, Glenoid cavity.

Three of the groups here regarded as suborders of the Squamata are frequently ranked as distinct orders, but their mutual relations are so close that it appears to harmonise better with the classification, adopted in other branches of the class, to include the whole of them in a single order. The Squamata may be regarded as occupying a position among Reptiles somewhat similar to that held by the Teleostei among Fishes, and the Passeres among Birds. That is to say, they are essentially typical Reptiles, which have attained to a considerable degree of specialisation; and while they have lost, on the one hand, all signs of kinship with the Amphibians, they exhibit, on the other, no traces of especial relationship with the Birds. That this order has originated from the Rhynchocephalia there seems but little doubt; but we are very much in the dark as to when or how the divergence took place.

Suborder 1. Lacertilia.—In the true Lizards the four limbs are usually well developed (fig. 1041) but in some cases one or both pairs are wanting. The ali- and orbitosphenoidal regions of the skull are imperfectly ossified; the superior temporal arcade is generally present; the quadrate articulates with the pterygoid; the nasals form a part of the narial aperture; and the rami of the mandible unite by suture. The vertebræ are in some instances amphicœlous; they usually have no zygosphenes, and the number in the cervical region does not exceed nine. When limbs are present the pectoral girdle is complete; and the terminal phalangeals of the feet are clawed. Dermal scutes are sometimes present; and these may be developed on the upper surface of the skull, so as to roof over the supratemporal fossæ. Existing Lizards are divided into twenty families, but only those will be noticed which occur in the fossil state.

We may commence our notice with a few Mesozoic forms, of which the family position is not yet determined. The earliest

known form appears to be *Macellodus* (with which *Saurillus* is either identical or very closely allied), from the English Purbeck; a small Lizard with pleurodont dentition, dermal scutes, and procœlous vertebræ. *Adriosaurus* is a larger form from the Lower Greensand of Austria, also having dermal scutes and procœlous vertebræ, but of which the dentition is unknown. An allied Continental Mesozoic form has received the name of *Hydrosaurus*, which is, however, a synonym of *Varanus*. In the Cambridge Greensand an imperfect femur and a vertebra indicate a Lizard of the size of some of the existing Monitors, but of which the affinity cannot even

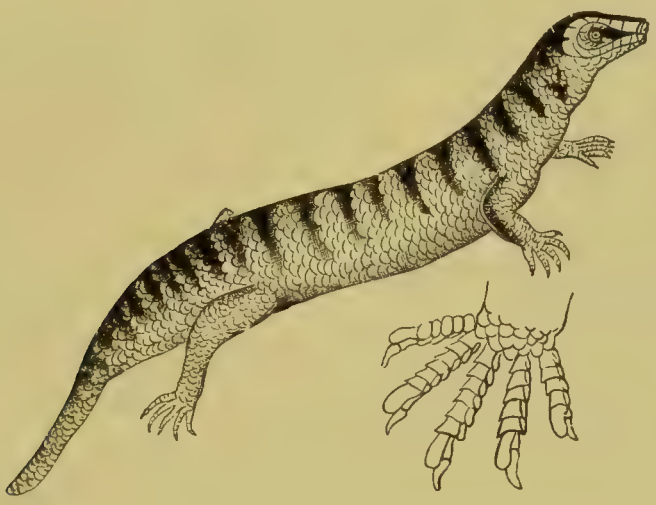


Fig. 1041.—The common Skink (*Scincus officinalis*). Reduced.

be conjectured. In the English Chalk occur the imperfectly known genera *Coniasaurus* and *Raphiosaurus;* the former having expanded, and the latter acute teeth.

Here also may be mentioned several genera from the Tertiaries of North America, of which the family position cannot yet be determined. The Eocene forms have been named *Tinosaurus* and *Thinosaurus*, and those from the Miocene *Aciprion*, *Platyrhachis*, and *Cremastosaurus*. *Notosaurus*, from the Tertiary of Brazil, has amphicœlous vertebræ, and may be a Rhynchocephalian.

Family Agamidæ.—The Agamoid Lizards constitute a large family, mainly characteristic of Asia, but also occurring in Europe, Africa, Australia, and Polynesia. The supratemporal fossa is not roofed over; the dentition is acrodont; and the premaxillæ are separate. Specimens referred to the type genus *Agama* have been obtained from the Upper Eocene Phosphorites of Central France; while the Pleistocene of Australia has yielded a skull indistinguish-

able from that of the existing Frilled Lizard (*Chlamydosaurus Kingi*) of the same country.

Family Iguanidæ.—The Iguanoids are readily distinguished from the *Agamidæ* by their pleurodont dentition (fig. 1042), and the presence of zygosphenal articulations to their vertebræ (fig. 1043). Nearly all the genera are now confined to the New World. In the Upper Eocene (Oligocene) Phosphorites of Central France there occur, however, fragments of jaws which have been referred to the typical American genus *Iguana;* that term being used in a wider sense than in recent herpetology. Vertebræ also occur in the approximately equivalent deposits of Hordwell in Hampshire (of which one is represented in fig. 1043), which agree in the presence of small zygosphenes with those of existing Iguanas, and have been provisionally referred to the French species. The name *Iguanavus* has been applied to remains of a member of this family from the Eocene of North America.



Fig. 1042.—Inner view of left ramus of the mandible of *Iguana*.

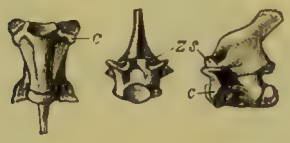


Fig. 1043.—Vertebra of *Iguana europæa*, viewed from the hæmal, anterior, and lateral aspects; from the Upper Eocene of Hampshire. *zs*, Zygosphene; *c*, Costal tubercle.

Family Anguidæ.—The *Anguidæ* are characterised by the presence of scutes roofing over the supratemporal fossæ; by the separation of the premaxillæ and the nasals; the more or less completely pleurodont dentition; and the presence of dermal scutes covered with minute tubercles. The genus *Ophisaurus* (*Pseudopus*), in which the limbs are either wanting or are reduced to rudiments of the pelvic pair, is represented in the Middle Miocene of Gers, in France, and the Lower Miocene of Rott, near Bonn; some of the species having been originally described under the name of *Anguis*. *Propseudopus*, from the Middle Miocene of Steinheim, in Bavaria, is distinguished from *Ophisaurus* by its stronger dentition and the presence of a double row of teeth on the vomer. The genus *Peltosaurus* and the allied *Exostinus*, of the Miocene of North America, may be included in this family; to which we may also refer several European and American Upper Eocene genera which have been regarded as constituting a distinct family under the names of *Placosauridæ* and *Glyptosauridæ*. Among these *Placosaurus* (*Palæovaranus*), from the Upper Eocene of France and England, has teeth resembling those of the Slow-worm (*Anguis*), which were originally regarded as belonging to a Varanoid; the vertebræ (fig. 1044) are not unlike

those of the existing *Diploglossus*, and the limbs were well developed. Another Anguoid, with blunt cylindrical teeth, from the Quercy Phosphorites, was originally referred to the Scincoid genus *Eumeces* (*Plestiodon*), but its generic position must for the present remain undecided. In North America we have *Glyptosaurus*, from the Bridger Eocene of Wyoming, in which the vertebræ have rudimental zygosphenes; the large *Saniva*, of which the dermal scutes are unknown; and the apparently allied *Xestops* (*Oreosaurus*). The vertebræ of these genera, like those of existing *Anguidæ*, present a strong resemblance to those of the next family, as may be seen by comparing fig. 1044 with fig. 1045.



Fig. 1044.—Vertebra of *Placosaurus margariticeps*, viewed from the hæmal, anterior, and lateral aspects; from the Upper Eocene Phosphorites of Central France. *c*, Costal tubercle.

Family Varanidæ.—The Monitors include the largest known Lizards; one of the fossil species attaining a gigantic size. They are confined to the Old World and Australia; and appear to be unknown before the Pliocene. The skull has no postorbital bar; the supratemporal fossæ are not roofed over by bony scutes; and both the premaxillæ and the nasals are united. The dentition is pleurodont; and the teeth are large and pointed, and confined to the jaws. The vertebræ are characterised by their broad and flat centra (fig. 1045); and dermal scutes are wanting. All the known forms may be included in the single genus *Varanus*.

In existing forms the dorsal vertebræ are elongated, and have broad neural spines; and the largest species attains a length of seven feet. In a fossil state this group is represented by remains from the Pleistocene of Madras apparently referable to the living *V. bengalensis*. Other vertebræ, again, found in the corresponding cave-deposits of Queensland, not improbably belong to one or more of the species still inhabiting that region. In a second and extinct group the dorsal vertebræ are relatively shorter and wider, and have narrower neural spines; the two known species being of very large size. The smaller of the two is *V. sivalensis*, from the Pliocene of the Siwalik Hills of India, of which a dorsal vertebra is shown in fig. 1045. Another vertebra is, however, larger than the figured specimen; and the total length of the animal was probably at least twelve feet. These dimensions were, however, greatly exceeded by the huge *V. priscus*, of the Pleistocene of Australia, in which

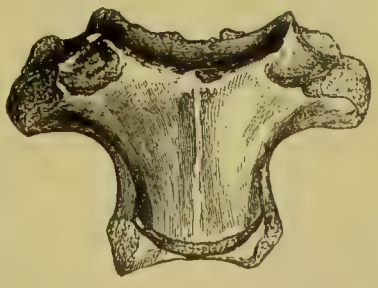


Fig. 1045.—Hæmal aspect of a dorsal vertebra of *Varanus sivalensis*; from the Pliocene of the Siwalik Hills.

the vertebræ are three times the size of those of *V. sivalensis*, and the total length did not probably fall short of thirty feet. This species was originally described by Sir R. Owen under the name of *Megalania;* certain remains which were referred to it having subsequently proved to be Chelonian. An imperfectly known species, from the Lower Pliocene of Attica, may perhaps belong to the former group.

It may be well to mention here that Sir R. Owen has described two peculiar blunt and pleurodont teeth of a large lizard from the Pleistocene of Queensland under the name of *Notiosaurus*, which is, however, preoccupied by the genus *Notosaurus* (p. 1139). It is just possible that these teeth may be referable to *Varanus priscus*, in which event the generic term *Megalania* would have to be retained for that form.

Family Teiidæ.—In this family, which is confined to America, the supratemporal fossæ of the skull are not roofed over, the dentition is pleurodont or subacrodont; the teeth, although variable in form, are always solid at the base; and there are no dermal scutes. An existing species of *Tupinambis* is represented in the Pleistocene cave-deposits of Brazil.

Family Lacertidæ.—In the *Lacertidæ* the supratemporal fossæ are roofed over by bone; the premaxillæ are united; the dentition is pleurodont, the bases of the teeth being hollow; and there are no dermal scutes. All the genera belong to the Old World. Remains of the existing *Lacerta ocellata* occur in the Pleistocene of France, and extinct species referred to the same genus have been described from the Miocene and the Upper Eocene Phosphorites of the same country.

Family Scincidæ.—The Scincoid Lizards form a large cosmopolitan family, characterised by the bony scutes roofing over the supratemporal fossæ; the separate or imperfectly united premaxillæ; the pleurodont dentition; and the presence of dermal scutes. *Dracænosaurus*, of the Lower Miocene of France, is an extinct genus with molariform teeth, probably allied to the existing *Scincus* (fig. 1041) or *Chalcides*.

Suborder 2. Rhiptoglossa.—The *Chameleontidæ*, or Chameleons, differ from the Lacertilia in that the nasals do not enter into the borders of the nares; the pterygoid does not articulate with the quadrate; and, although limbs are present, there are no clavicles or interclavicle. The dentition is acrodont. All the existing forms are Old World; but Dr Leidy has described part of a mandible from the Upper (Bridger) Eocene of Wyoming, which he refers to the type genus *Chameleon*.

Suborder 3. Dolichosauria.—This group was originally formed for the reception of the genus *Dolichosaurus*, from the English Chalk; which is a small snake-like Lizard, with more than nine

vertebræ in the neck, and well-developed limbs. The vertebræ have zygosphenal articulations. *Acteosaurus*, from the Cretaceous of Austria, is an allied form.

Suborder 4. Pythonomorpha.—The Mosasauroids are carnivorous marine Reptiles, frequently of large dimensions, and ranging in time from the Upper Greensand to the topmost Cretaceous, with a cosmopolitan distribution. The body is much elongated. The skull (fig. 1047) presents a strong resemblance to that of the *Varanidæ* among the Lacertilia, and has the nasals and premaxillæ welded together, the quadrates very loosely articulated, teeth on the pterygoids as well as in the jaws, and frequently ossifications in the sclerotic of the eye. The teeth are large and sharp, and anchylosed by expanded bases to the summits of the jaws. There may be zygosphenal articulations to the vertebræ, and the cervical region may include more than nine vertebræ. The clavicles are always, and the interclavicle and sacrum generally, wanting; but Professor Marsh figures a sternum in one genus. The limbs are modified into paddles (fig. 1046), with no claws to the terminal phalangeals, and no foramen to the humerus. The development of the pelvis is, moreover, but imperfect, and at least the majority of forms appear to have been devoid of dermal scutes, although Professor Marsh has recorded their presence in one genus.

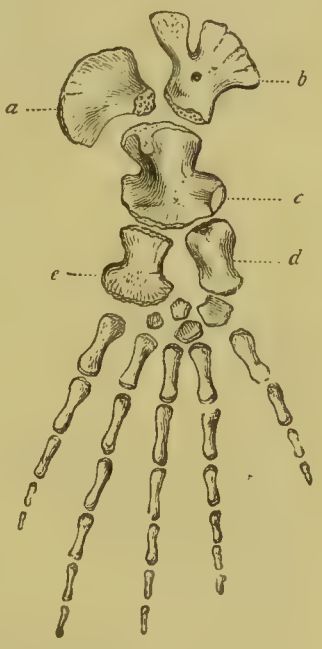


Fig. 1046.—Right pectoral limb of *Platycarpus;* from the Cretaceous of North America. One-twelfth natural size. *a*, Scapula; *b*, Coracoid; *c*, Humerus; *d*, Radius; *e*, Ulna. (After Marsh.)

Family Plioplatycarpidæ. — The least specialised form seems to be the genus *Plioplatycarpus*, of the Upper Cretaceous of Holland, in which both an interclavicle and a sacrum are present; on which account its describer, M. Dollo, regards it as the type of a distinct family.

Family Mosasauridæ.—The whole of the remaining genera of the suborder may be included in this family. One of the well-known genera is *Clidastes* (from which *Edestosaurus* is regarded by Professor Cope as inseparable), from the Cretaceous of North America. This genus comprises numerous species, characterised by the extreme elongation of the body, and their small or medium size. In the skull the teeth, as in the next genus (fig. 1047) are continued to the extremity of the premaxillæ; the vertebræ are

long, and have zygosphenal articulations; the humerus is short; and the chevrons are anchylosed to the centra. *Sironectes* is an allied genus from the same deposits, in which the chevrons are not anchylosed to the vertebræ. *Platycarpus*[1] (*Lestosaurus*, *Taniwhasaurus*), which is found in the Cretaceous of North America, New Zealand, and perhaps Europe, differs from both the preceding

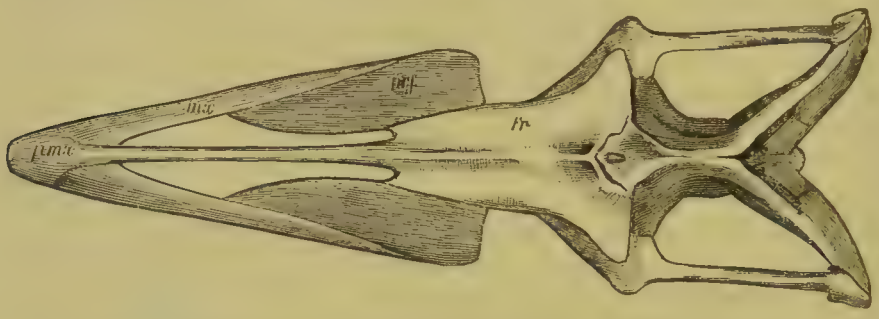


Fig. 1047.—Frontal aspect of the cranium of *Platycarpus curtirostris*; from the Upper Cretaceous of North America. Greatly reduced. *pmx*, Premaxilla; *mx*, Maxilla; *fr*, Frontal; *prf*, Prefrontal. (After Cope.)

genera by the absence of zygosphenes; the chevrons being free and the humerus (fig. 1046) short and broad. With the genus *Liodon*, in which Professor Cope includes *Tylosaurus* (*Rhinosaurus*) of Professor Marsh, we come upon forms attaining gigantic dimensions, in which the body is proportionately shorter than in the above-mentioned genera, and the vertebræ are always without zygosphenes. In *Liodon* itself the extremity of the premaxillæ is devoid of teeth, and forms a cylindrical rostrum; the teeth are smooth and more or less laterally compressed; the humerus is long; and the chevrons are free. It occurs in the Cretaceous of Europe, North America, and New Zealand. *Hainosaurus*, again, of the Upper Chalk of Mons, agrees with *Liodon* in its edentulous rostrum and free chevrons, but has teeth of three types. Some of the teeth are subcylindrical, and others compressed, with serrated cutting edges like those of *Megalosaurus*. The total length of this huge Reptile is estimated at about 40 feet. The typical genus *Mosasaurus* is definitely known from the topmost Cretaceous of Maastricht in Holland, and the Cretaceous of North America; the type species from Maastricht having been made known to science in the last century. It is characterised by the premaxillæ being toothed to their extremity; by the teeth having their crowns faceted and more or less compressed; as well as by the greater number of the chevrons being anchylosed to the vertebræ. The fine skull of *M. Camperi* represented in the accompanying woodcut was obtained from Maastricht previously to 1785, and is preserved

[1] Amended from *Platecarpus*.

in the Paris Museum. This species is estimated to have attained a length of 25 feet. Closely allied to *Mosasaurus* is *Pterycollasaurus*, which is, however, readily distinguished by the complete union of the pterygoids in the middle line—a feature unknown elsewhere

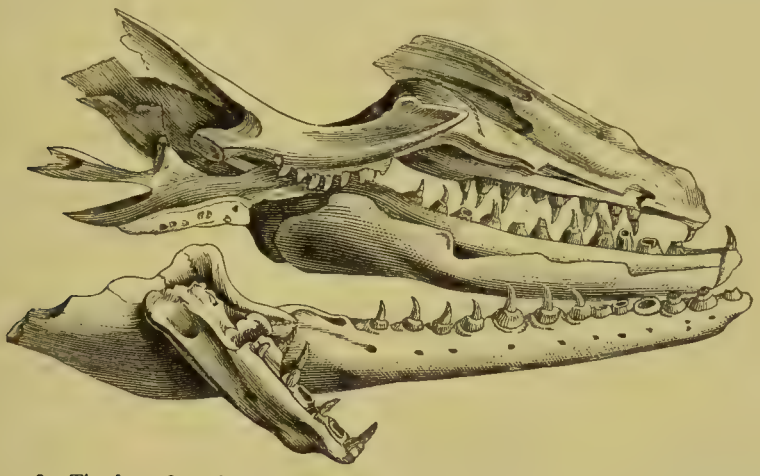


Fig. 1048.—The imperfect skull of *Mosasaurus Camperi;* from the Upper Cretaceous of Maastricht. Much reduced. The displaced bone in the left bottom corner is the left pterygoid, the corresponding bone of the opposite side being in its natural position above.

in the whole order. The only known species is *P. Maximiliani*, of the Cretaceous of Brazil. Finally, the genus *Baptosaurus*, of the Cretaceous of North America, is distinguished from all other genera by the complete union of the hæmal spines of the cervical vertebræ

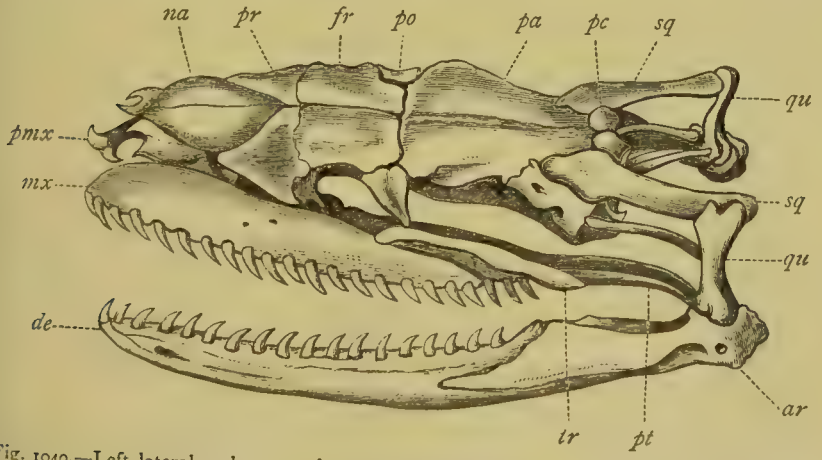


Fig. 1049.—Left lateral and upper view of the skull of *Boa*. *pmx*, Premaxilla; *na*, Nasal; *pr*, Prefrontal; *fr*, Frontal; *po*, Postfrontal; *pa*, Parietal; *pc*, Proötic; *sq*, Squamosal; *qu*, Quadrate; *pt*, Pterygoid; *tr*, Transverse; *mx*, Maxilla; *ar*, Articular; *de*, Dentary.

with the centra. The Mosasaurs attained their maximum development at a time when the Ichthyosaurs were on their decline.

The very imperfectly known *Cetarthrosaurus*, of the Cambridge Greensand, which Mr Hulke refers to this order, is noticed among the Ichthyopterygia.

Suborder 5. Ophidia.—The Serpents and Snakes constituting the last division of the Squamata present the following distinctive features: The body is greatly elongated (fig. 1051, *bis*), and the vertebral column divisible only into a trunk and a caudal region. The alisphenoidal region of the skull is fully ossified; there is no temporal arcade, parietal foramen, or columella; the quadrate and the bones of the palatal and maxillary regions are loosely attached to the skull (fig. 1049); the premaxillæ are more or less aborted and usually edentulous; and the two rami of the mandible are connected only by ligament. The vertebræ (fig. 1050) have zygosphenes; but there is no sacrum, and chevrons are also wanting. There is, moreover, no sternum, nor any trace of the pectoral girdle or limbs; but in some cases there are rudiments of the pelvic girdle and limbs. Dermal scutes are invariably wanting. This suborder is divided into three sections; but since its palæontological history is but imperfectly known, only very brief mention will be made of those families represented in a fossil state. With the exception of an imperfectly known form from the Chalk, described under the name of *Cimoliophis*, all the known fossil forms are of Tertiary or Post-tertiary age. The next earliest genus is *Helagrus*, of the Lowest (Puerco) Eocene of North America, in which the imperfect development of the zygantrum of the vertebræ indicates very generalised affinities.

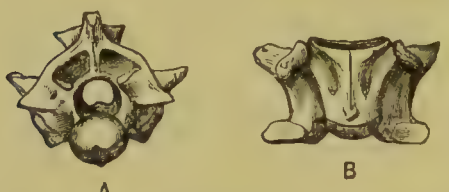


Fig. 1050.—Posterior (A) and hæmal (B) views of a trunk vertebra of *Python molurus*; from the Pleistocene of India.

Family Colubridæ.—The first existing family of the section Colubriformes, or Innocuous Snakes, contains the great bulk of the suborder; and, with the exception of Australia, is represented in nearly all temperate and warm regions. The Indian genus *Ptyas* is probably represented in the Pleistocene of Madras by the existing *P. mucosus*. In the Middle Miocene of France we have the extinct *Pilemophis* closely related to the modern *Tropidonotus*, or common English Snake; while the existing genus *Elaphis* occurs in the Upper and Lower Miocene of various parts of the Continent. A species of *Periops* closely allied to one now living in Egypt occurs in the Pleistocene of Coudes, in the south of France; and *Thamnophis*, from the Middle Miocene of the latter country, is said to be allied to *Elaphis*.

Family Pythonidæ.—The Pythons, or Rock Snakes, are now

confined to Africa, Asia, or Australia; and, with the next family, include the largest existing representatives of the suborder. They have teeth in the premaxilla; and all of them are good swimmers. Remains of the existing Indian *Python molurus* (fig. 1050) are found in the Pleistocene of Madras; and not improbably also in the Pliocene of the Punjab; while in the Pleistocene of Australia occur vertebræ probably referable either to *Narboa* or *Liasis*, which now inhabit that continent. From the Upper Eocene (Lower Oligocene) freshwater deposits of Hampshire, and the equivalent Phosphorites of Central France, we have the genus *Paleryx* (*Palæopython*), which is apparently nearly related to *Python*. Finally, *Scytalophis*, from the Quercy Phosphorites, is said to connect the *Pythonidæ* with the *Tortricidæ*.

Family Boidæ.—The Boas are at the present day confined to the New World, and differ from the *Pythonidæ* by the absence of premaxillary teeth (fig. 1049). The genera *Boavus*, *Lithophis*, and *Lestophis* (*Limnophis*), of the Upper Eocene of North America, are probably referable to this family. *Protagrus*, from the same deposits, may also be provisionally included in this family; to which it has been suggested that *Botrophis*, of the French Miocene, may likewise belong.

Family Erycidæ.—The members of this family are small Snakes allied to the *Boidæ*, but having a much shorter and non-prehensile tail. *Scaptophis*, of the Middle Miocene of France, is regarded as allied to the existing African *Eryx*; while in the Miocene of North America we have *Aphelophis*, *Calamagrus*, and *Ogmophis*, all of which appear to be more or less closely related to the genus *Charina* now inhabiting the same regions.

Family Palæophidæ.—Here we may provisionally place the family formed for the reception of the extinct genus *Palæophis*,

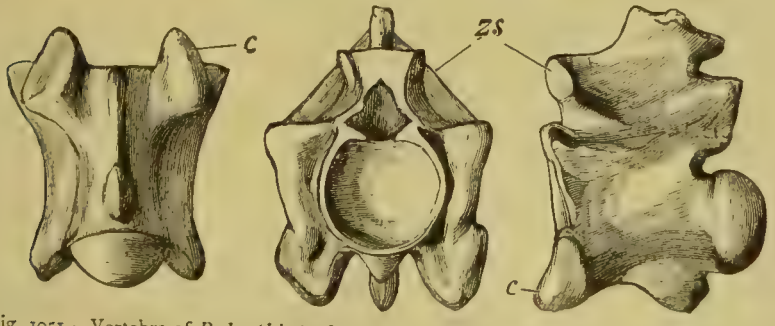


Fig. 1051.—Vertebra of *Palæophis typhæus*; from the Middle Eocene of England. The neural spine is wanting. *c*, Costal tubercle; *zs*, Zygosphene.

from the Lower and Middle Eocene of Europe, comprising very large Serpents, which were probably of marine habits. The ver-

tebræ (fig. 1051) differ from those of the *Pythonidæ* (fig. 1050) by their much taller neural spines, the lower position of the costal articular surfaces, the less divergence of the zygapophyses, and by the stronger development of the hæmal ridge on the inferior aspect of the centrum, which often carries well-marked processes at its two extremities. The type genus *Palæophis* is represented by three English species, of which the largest is estimated to have attained a length of 20 feet. In the Eocene of North America we have closely allied forms reaching to a length of 30 feet, which are referred by Professor Marsh to a distinct genus under the name of *Titanophis* (*Dinophis*), but which Professor Cope regards as indistinguishable from *Palæophis*. By Sir R. Owen these snakes are regarded as allied to the existing marine Sea-snakes or *Hydrophidæ*.

Family Elapidæ. — The first existing family of the section Colubriformes Venenosi includes the Cobras (*Naia*, fig. 1051, *bis*) and Coral-snakes (*Elaps*). The former genus probably occurs in the Pleistocene of Madras; and perhaps also in the Middle Miocene of Steinheim, in Bavaria.

Family Viperidæ.—The present and following families constitute the section Viperiformes; characterised, among other features, by the perfect development of the poison-apparatus. A snake from the Upper Miocene of Switzerland has been referred by M. Rochebrune to the existing genus *Bitis* (*Echidna*); having been originally described under the name of *Coluber Kargi*.

Family Crotalidæ.—The Pit-Vipers and Rattlesnakes are confined at the present day to Asia and America. The genus *Neurodromicius*, from the Miocene of North America, is provisionally referred by Professor Cope to this family; while *Laophis*, from the Tertiary of Salonica, has also been regarded as a member of the same group.

Ordinal Position Uncertain.—It will be convenient to mention here two imperfectly known genera from the English Purbeck, of which the ordinal position cannot at present be determined. They were regarded by Sir R. Owen as belonging to the Lacertilia, but their teeth are much more of a Dinosaurian type. The first genus, *Nythetes* (*Nuthetes*), is represented by a species of the size of some of the existing *Varanidæ*, but has teeth closely resembling those of the *Megalosauridæ*, although it is said that they were not implanted in distinct sockets, and were anchylosed to the bone. The second genus, *Echinodon*, is a smaller form, in which the teeth present a striking resemblance to the much larger ones of the Dinosaurian genus *Scelidosaurus;* they were implanted in imperfect sockets.

Here also may be mentioned the remarkable genus *Atoposaurus*, from the Kimeridgian lithographic limestones of Bavaria, which includes two species of small Lizard-like Reptiles, presenting the

following peculiar features. The manus seems to be of a Rhynchocephalian type; but the pes has only four digits, in which the phalangeals number 2, 3, 4, 4, or the same as in the Crocodilia. The proximal bones of the carpus are also elongated, as in that order; and the radius and ulna in the pectoral, and the tibia and fibula in the pelvic limb, are respectively in close apposition. The mandibular symphysis is long; and the dentition is said to resemble that of the *Geckonidæ* among the Lacertilia. The above characters point to a curious blending of Squamatine and Crocodilian features.

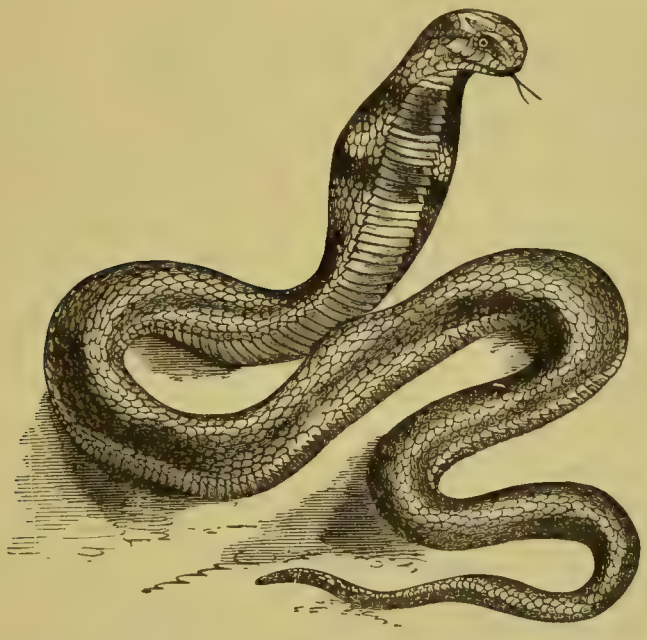


Fig. 1051, *bis*.—The African Cobra (*Naia haje*). Reduced.

CHAPTER LV.

CLASS REPTILIA—continued.

Orders Dinosauria, Crocodilia, and Ornithosauria.

Archosaurian Branch. — The three orders constituting this branch comprise the most highly developed of all Reptiles, and those which make the nearest approach in their organisation to the Avian type. They also include the largest forms yet known, not only among Reptiles, but also among all Vertebrates adapted for a life on land. The following features are common to the entire branch. The teeth are very generally implanted in distinct sockets; are never anchylosed to the bones of the jaws; and are exclusively confined to the premaxilla, maxilla, and dentary bones. Both the pectoral and pelvic limbs are always well developed; the cranium has no parietal foramen, but is furnished with both a superior and an inferior temporal arcade (as is shown in the figure of the Crocodilian skull on p. 1181); the quadrate is firmly fixed among the adjacent bones; and there is frequently no columella. The anterior ribs have a distinct capitulum and tuberculum; the dorsal vertebræ carry long transverse processes, which may be placed entirely on the arch; and there may be more than two vertebræ in the sacrum. There is never a T-shaped interclavicle, and the only indication of the precoracoid is afforded by the fontanelle in the coracoid, which indicates its original duality. The humerus has no foramen, but an ectepicondylar groove may occur. The proximal row of the tarsus comprises two bones, representing the astragalus and calcaneum. Abdominal ribs are generally present. The number of phalangeals in the limbs approximates more or less closely to that obtaining in the Streptostylic branch, although in some cases there is a reduction. The lateral surface of the mandibular ramus may have a vacuity. As a rule the centrum of the atlas vertebra forms an odontoid process more or less closely attached to the centrum of the axis; the arch of the former being

supported by the crescent-shaped first intercentrum. Generally the second intercentrum, like that of Birds, was likewise fused with the centrum of the axis; but in one Dinosaur (? *Megalosaurus*) this element exists as a distinct wedge-like bone.

In the pelvis the pubis and ischium never form the broad and flattened plates found in the Synaptosaurian branch, and they frequently assume a more or less rod-like form with expanded extremities (fig. 1073). The ilium (*ibid.*) frequently presents an expanded form; and the obturator notch is never converted into a foramen.

Order VIII. Dinosauria.—The Dinosaurs comprise the largest land Reptiles; and while some of them approximate closely to the type of structure obtaining in Birds, others come so near to the more generalised Crocodilians that it is almost impossible to give any definition of the order that will separate it from the latter. It is, indeed, probable that in the Lower Trias there lived the common ancestors of the two orders, and the forms from the upper division of the same period indicate not only the close connection between these two groups, but also show some signs of affinity with the Rhynchocephalia.

It has recently been proposed to divide the Dinosauria into two orders, from the structure of the pelvis, for which the names Ornithischia and Saurischia have been proposed. If, however, this view be eventually accepted, it would be advisable to adopt the name Ornithopoda for the first division, and to restrict the term Dinosauria to the second, which would include the two groups here termed Theropoda and Sauropoda. In regard to the names of the suborders, it should be mentioned that Professor Cope first proposed the names Orthopoda and Goniopoda for the groups here termed Ornithopoda and Theropoda, on the ground that the relations of the tibia and fibula were essentially different in the two. According, however, to Professor Huxley, this alleged difference does not exist, and these names are therefore rejected by him.

This order is entirely extinct, and may be regarded as characteristic of the Mesozoic period; since it ranges from the Trias to the Uppermost Cretaceous of Maastricht, and the Laramie beds of the United States, and appears to have attained its maximum development in the Jurassic and Wealden. In space this order was widely distributed over Europe and North America; and it has also been met with in India and Africa.

Dinosaurs vary exceedingly in the contour of the body and limbs; which in some instances were more or less of a crocodilian type, but in others approach very markedly to the avian structure; the latter feature being most marked in the pelvis and hind limbs. The hind limbs were either moderately or excessively long; while the body

was sometimes defended by a bony dermal armour, which may carry long spines, but apparently was never composed of imbricating pitted scutes. The centra of the vertebræ are very generally amphicœlous; but are not unfrequently opisthocœlous in the cervical, and more rarely in the anterior dorsal region; and occasionally some of the caudals are procœlous. The neuro-central suture was usually persistent till an advanced period of life. As a general rule the sacrum includes from three to six vertebræ, but occasionally the number is reduced to two. The cervical ribs are not produced into spines directed antero-posteriorly; and there are no uncinate processes to the ribs. The rib-facets of the middle dorsal vertebræ may either form a "step" on the transverse process, as in the Crocodilia, or may be placed on the lamina of the arch. The skull has many features of that of the earlier Crocodilia, but also seems to approximate in some cases to the Rhynchocephalian type. The premaxillæ were but rarely fused together; and the union of the mandibular rami in the symphysis is cartilaginous. The teeth are generally more or less laterally compressed, frequently having serrated edges, and may be of complex structure; they were not always implanted in distinct sockets. The sternal region is imperfectly known, but it frequently comprised two paired bones, which may represent parts of the sternum. The limb bones may be either solid or furnished with a medullary cavity. The coracoid has a fontanelle, and is always short and rounded. In the pelvis (fig. 1060) the ilium has both the pubic and preacetabular processes well developed, the latter being in some cases greatly elongated; the pubis always takes a share in the formation of the acetabulum (of which the inner wall is unossified), and may be directed either forwards or backwards. The femur may have its head placed either obliquely (as in the Crocodilia) or at right angles to the condyles; and may or may not be furnished with an inner trochanter. The tibia, as in Birds, had a cnemial crest; and the astragalus was frequently flattened, and more or less closely applied to the lower end of the tibia.

Suborder 1. Ornithopoda.—This suborder is taken to include the Stegosauria of Professor Marsh, and embraces the most specialised forms. In the skull (figs. 1059, 1062) the anterior part of the premaxilla is devoid of teeth; there is no preorbital vacuity; the nares are placed at the extremity of the skull; and the teeth are more or less complex, and are frequently not set in distinct sockets. The vertebræ are solid throughout. The pectoral limb is considerably shorter than the pelvic; the limb bones may be either solid or hollow. The ilium generally has its preacetabular process much elongated (fig. 1060), although this is not the case in the type of *Camptosaurus* (fig. 1052), the ischium has an obturator process;

but the most striking and remarkable feature in the group, and one in which it differs from all others except Birds, is that the shaft of the pubis is directed backwards more or less nearly parallel with the ischium, while a shorter and thicker portion in advance of the acetabulum projects forwards. How remarkably this pelvic structure approximates to that of Birds may be seen by comparing figs. 1052 and 1060 with that of the pelvis of a Ratite Bird given in the sequel. Thus the large preacetabular process of the pubis of the Dinosaur corresponds with the much smaller but similarly situated



Fig. 1052.—The left side of the pelvis of *Camptosaurus dispar;* from the Upper Jurassic of North America. One-twelfth natural size. The upper bone is the ilium, that on the left the pubis, and that on the right the ischium. (After Marsh.)

pectineal process in the pelvis of the Ratite Birds (fig. 1107). In some cases the pubis had no median symphysis. All the more specialised members of the suborder appear to have walked habitually on the hind limbs alone. In this and the following suborder the length of the tibia is often nearly equal to that of the femur; and in *Hysilophodon* and *Compsognathus* the former bone, as in Birds, is the longer of the two.

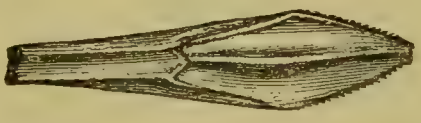


Fig. 1053.—Tooth of *Trachodon Foulki;* from the Upper Cretaceous of New Jersey. (After Leidy.)

Family Trachodontidæ. — The most specialised, as well as one of the most recent, families of the suborder, seems to be that typically represented by the genus *Trachodon* (*Hadrosaurus*). This family, although closely related to the next, is distinguished by having the teeth arranged in a number of vertical columns and articulating together so as to

form a kind of pavement. The type genus, of which a tooth is shown in fig. 1053, was first described from the Upper Cretaceous of the United States, but has been subsequently recorded from the Upper Greensand of Cambridgeshire. All the dorsal vertebræ are opisthocœlous. Five other genera—viz., *Diclonius*, *Cionodon*, *Monoclonius*, *Dyscanus*, and *Agathaumas*—from the Laramie beds of North America present a similar type of dentition, and have been referred to the same family; the first being probably identical with *Trachodon*. The Laramie beds, it should be observed, appear to be transitional between the Cretaceous and Eocene although referable to the former epoch. In the so-called *Diclonius* the skull, although presenting many of the features of that of *Iguanodon*, is much more elongated and depressed, and has the edentulous premaxillæ produced in advance of the large nares. *Orthomerus*,

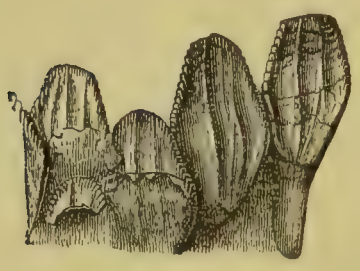
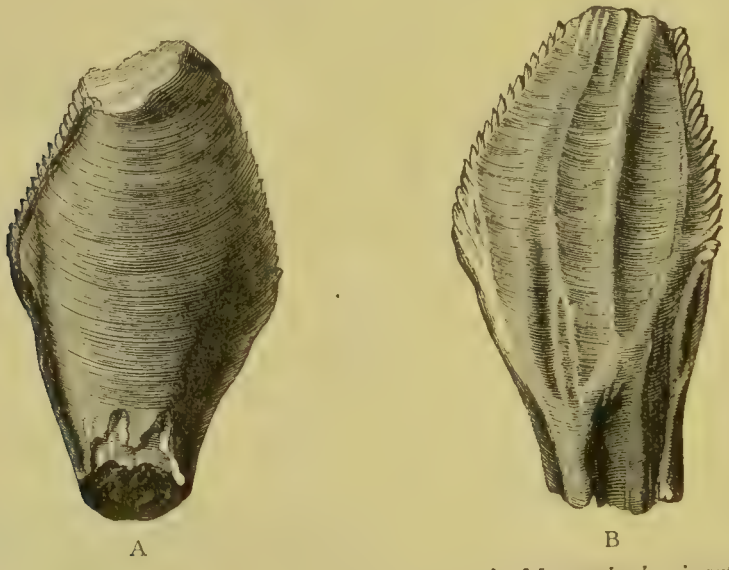


Fig. 1054.—Four lower teeth of *Iguanodon* in the jaw. Reduced.



A B

Fig. 1055.—Inner (A) and outer (B) aspects of a lower tooth of *Iguanodon bernissartensis*; from the Wealden of Sussex.

of the Upper Cretaceous of Maastricht in the Netherlands, may probably be also referred to this family, although it shows some signs of connection with the next.

Family Iguanodontidæ.—The characteristic features of this remarkable family are to be found in the hollow limb bones; the

slenderness and relative length of the pubis and ischium (figs. 1052, 1060); the avian characters of the femur, which has a large inner trochanter; the digitigrade hind-foot, furnished with either three or four digits and more or less elongated metatarsals; and the short pectoral limbs. The bones usually referred to the sternal region are typically hatchet-shaped, and have been regarded by some authorities as clavicles, although it seems more probable that they are connected with the xiphisternum. The cervical vertebræ were usually opisthocœlous; and the rib-facets in the middle dorsal region were placed on the arch. The teeth (figs. 1054, 1055) were arranged in a single row, and are very peculiar and characteristic. Thus they have flattened, diamond-shaped crowns, bearing strongly-marked serrations on the anterior and posterior borders, and one



Fig. 1056.—*Iguanodon bernissartensis.* The skeleton; from the Wealden of Belgium. About $\frac{1}{15}$ natural size. The scale indicates metres. (After Dollo.)

or more vertical ridges, some of which may themselves be serrated, on their outer aspect. The mandible, again, presents the peculiar feature of having a horse-shoe-like predentary bone at the extremity of the symphysis (fig. 1059). This predentary ossification is devoid of teeth; while the mandibular symphysis itself is deeply channelled. The family ranges from the Middle Jurassic to the Wealden and Neocomian of Europe; its members generally showing a gradual increase in size from the lower to the higher horizons. Like the members of the preceding family, the Iguanodonts habitually supported themselves on the hind limbs, as in the accompanying figure.

In the imperfectly known *Sphenospondylus* of the English Wealden, the anterior dorsal vertebræ were opisthocœlous, and all the dorsals had very low neural arches. In the type genus *Iguanodon*, which includes the largest forms, the skull (fig. 1059) is comparatively short, with large and terminal nares and no teeth in the premaxilla. In the typical forms, constituting the Euiguanodont group, the dorsal vertebræ (fig. 1058) are amphicœlous, those in the anterior part of the series having very tall neural arches and compressed centra; while the sacral vertebræ are anchylosed together, and have rounded inferior, or hæmal, surfaces. In the pelvis (fig. 1056) the ilium is shallow, with a sharply pointed post-acetabular process; while the pubis is much shorter than the

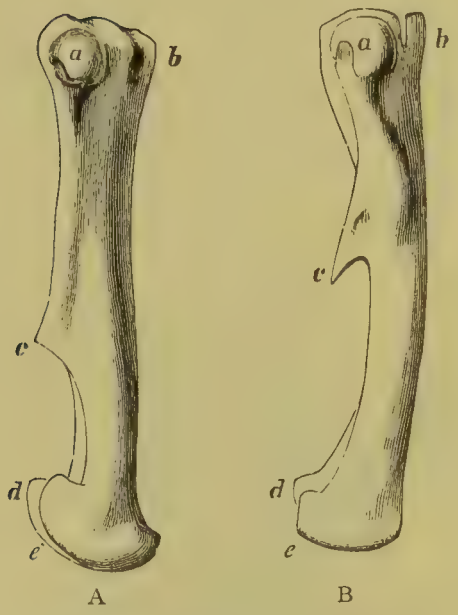


Fig. 1057.—Inner aspect of the left femur of *Iguanodon bernissartensis* (A), and of *Camptosaurus Leedsi* (B). Reduced to same size. *a*, Head; *b*, Lesser trochanter; *c*, Inner do.; *d*, Ectocondyle; *e*, Entocondyle.

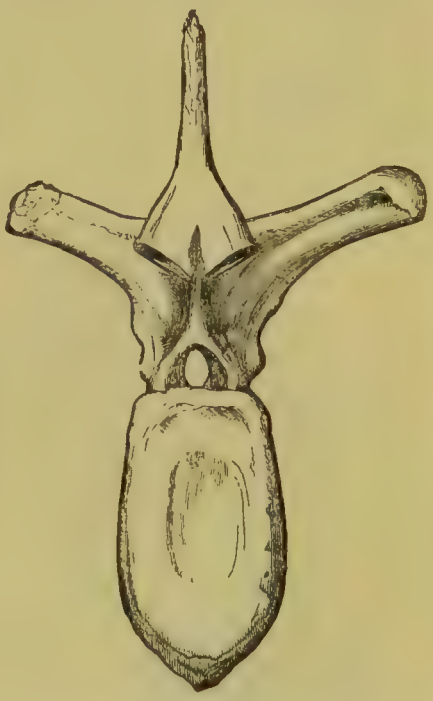


Fig. 1058.—Posterior aspect of anterior dorsal vertebra of *Iguanodon bernissartensis*; from the Wealden of the Isle of Wight. One-sixth natural size. (After Seeley.)

ischium (which is twisted on itself), and does not form a symphysis. The femur (fig. 1057, A) is characterised by the inner trochanter (*c*) forming a crest directed almost immediately backwards, while its shaft is nearly straight. The foot had only three functional digits, of which the metatarsals were short and thick, and the phalangeals broad and flat; while in the manus the one phalangeal of the first digit, or pollex, was modified into a stout conical spine. As in the other members of the family, the astragalus, although not

anchylosed to the tibia, was closely applied to its distal extremity, and thus rendered the structure of the ankle-joint (as in many other members of the order) essentially similar to that of a Bird.

It may be observed that the inner trochanter of the femur corresponds to the small one found in some Birds, which gives attachment to the femoro-caudal and ischio-femoral muscles, and it is interesting to find, from the observations of M. Dollo, that its form in *Iguanodon* is that which agrees with the Avian type.

Iguanodon ranges from the Wealden to the Lower Greensand, and hitherto has only been described from Europe. The two representatives of the typical or Euiguanodont group occur in the Upper Wealden and Lower Greensand, and comprise *I. Mantelli*, and the larger *I. bernissartensis* (fig. 1056); these two species being also distinguished from one another by the number of the sacral vertebræ, and the contour of the ilium and femur.

The length of the entire body of the larger *I. bernissartensis* is estimated at about 33 feet. The history of the gradual reconstruction of the skeleton of this genus affords an instructive instance of the results which may be attained by careful and patient study of fragmentary remains.

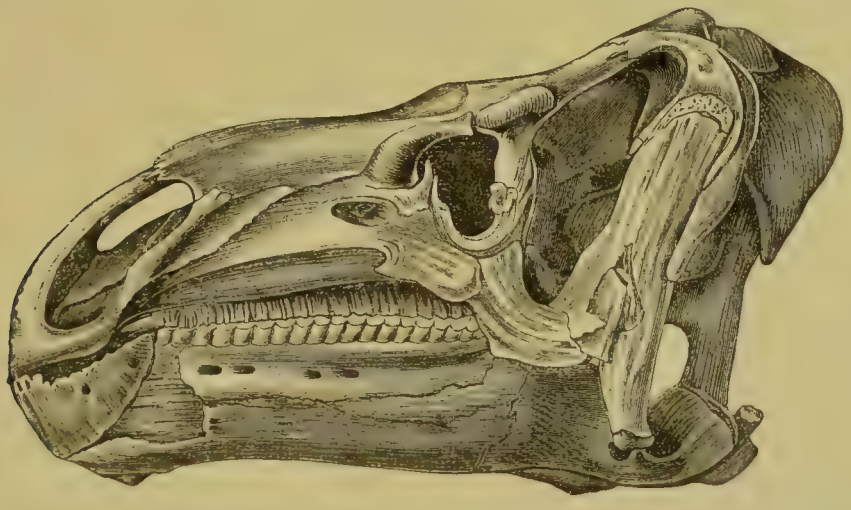


Fig. 1059.—Left lateral aspect of the skull of *Iguanodon bernissartensis;* from the Wealden of Belgium. Much reduced. The anterior aperture is the nares; the middle one the orbit; and the posterior the infratemporal fossa. The predentary bone is seen at the extremity of the mandible. (After Dollo.)

By the labours of the late Dr G. Mantell of Lewes, in the first half of this century, a considerable knowledge was acquired of the greater part of the skeleton, although the structure of the pectoral and pelvic girdles remained a puzzle. The structure of the latter was, however, after more than one ineffectual attempt, finally solved by the labours of Professor Huxley and Mr J. W. Hulke.

In the Wadhurst Clay, or Lower Wealden, of Sussex, we meet with three species of *Iguanodon* which connect the preceding typical

forms with the undermentioned genus *Camptosaurus*. *I. Dawsoni* is a form intermediate in size between *I. Mantelli* and *I. bernissartensis*, characterised by the less compressed centra and lower arches of the dorsal vertebra; and also by the form of the ilium (fig. 1060, *Il*), which is of great depth, and has a deep and rounded postacetabular process, while the preacetabular process has a horizontal inferior plate. In the smaller *I. Fittoni* the ilium is equally deep, but has the postacetabular portion narrowed to a point laterally, with a distinct inferior horizontal plate; while the sacrum has laterally com-

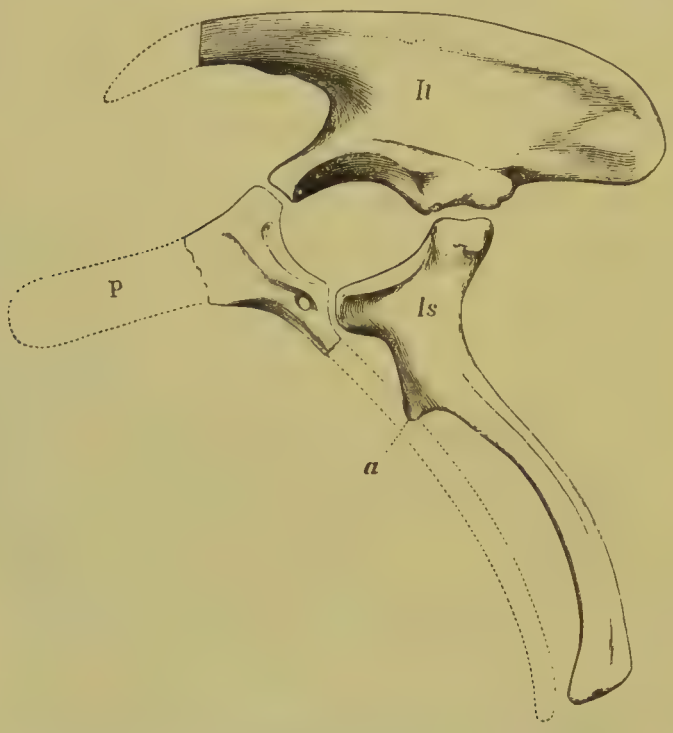


Fig. 1060.—Left pelvic bones of Lower Wealden Iguanodons. One-sixteenth natural size. *Il*, Ilium of *Iguanodon Dawsoni*; *P*, Imperfect pubis of do.; *Is*, Ischium of *I. hollingtoniensis*; *a*, Obturator process of ischium.

pressed vertebræ like those of *I. Mantelli*. The posterior portion of the ilium of this species is indeed almost indistinguishable from that of *Camptosaurus* (fig. 1052). Finally, in *I. hollingtoniensis*, which agrees approximately in the proportions of the limbs with *I. Mantelli*, the femur had a curved shaft and pendant trochanter as in *Camptosaurus* (fig. 1057, B); while the sacrum had the vertebræ remaining separate from one another, with their inferior surfaces flattened, as in that genus, with which this species also agreed in the contour of the ischium (fig. 1060, *Is*), which has a stout shaft not twisted upon itself. This species agreed, however,

with the typical species of the genus in having the pollex modified into a conical spine, and thereby differed from *Camptosaurus*, although indicating how the one genus passed into the other. It is not improbable that the large Iguanodont from the Upper Jurassic of the United States, described as *Camptosaurus amplus*, should be referred to this group of *Iguanodon*, since it has but three functional digits in the pes.

With the genus *Camptosaurus* (*Camptonotus*), we come to forms which are usually of smaller size than the preceding. It occurs typically in the Upper Jurassic of North America; but certain forms, from the English Oxford and Kimeridge Clays, to the latter of which the name *Cumnoria* has been applied, as well as a Wealden species, do not appear to be generically separable. This genus has teeth of somewhat simpler structure than those of *Iguanodon*, and is further characterised by the flattened hæmal surfaces of the centra of the sacral vertebræ, which appear to have remained separate throughout life; by the short preacetabular process of the ilium (fig. 1052) of the type species; by the equality in the length of the pubis and ischium; by the pendant, or downwardly directed, inner trochanter of the curved femur (fig. 1057, B); and the presence of five digits of normal structure in the manus, and typically of four in the pes. The length of the femur of the type species is some 21 inches. The English forms are not fully known; but so far as this is the case they agree in essential characters with the type: the structure of the manus and pes is, however, unfortunately unknown. *C. Leedsi*, of the Oxford Clay, is known only by the femur (fig. 1057, B), which measures a little over one foot in length; while in the Kimeridgian *C. Prestwichi* (the type of *Cumnoria*) we are acquainted with the greater part of the vertebral column, in which the dorsals have tall neural arches, while the ilium has a long preacetabular process like that of *Iguanodon*. The Wealden *C. valdensis* is typified by a femur. *Laosaurus* is an allied form from the Upper Jurassic of the United States, distinguished by its amphicœlous cervical vertebræ. The imperfectly known *Cryptodraco* (*Cryptosaurus*), from the Oxford Clay of England, is characterised by the great stoutness of the femur, which exceeds a foot in length, and has a straight shaft, with an inner trochanter like that of *Iguanodon bernissartensis*, but differs from the corresponding bone of all other members of the family in the absence of a groove on the anterior aspect of the lower end between the condyles.

Lastly, we come to the consideration of *Hypsilophodon*, the smallest and least specialised representative of the family, which is now well known to us through the labours of Mr J. W. Hulke. In this genus, which occurs in the Upper Wealden of England, the general structure of the pelvis, as well as the pendant inner tro-

chanter of the femur, resemble the corresponding elements of *Camptosaurus;* and there are likewise four functional digits in the pes, of which the metatarsals are elongated; while the teeth, which also occur in the hinder half of the premaxilla, are somewhat simpler than those of *Iguanodon.* In conclusion, we may mention two imperfectly known forms which are evidently related to this family. Of these, *Mochlodon*, from the Upper Greensand of Austria, is characterised by the absence of the channelled mandibular symphysis characteristic of typical forms; while *Craspedodon*, from the Upper Cretaceous of Belgium, is a very small Dinosaur, merely known by its teeth, which are more complex than those of *Iguanodon.*

Family Scelidosauridæ.—This family includes a group of remarkable Dinosaurs of medium dimensions, characterised by being clad in a stout dermal armour, usually consisting of detached scutes and long spines, but sometimes taking the form of a solid carapace completely covering the lumbar region. The rami of the mandible are slender and tapering, but it is not known whether a predentary bone was present. The teeth (fig. 1061) have laterally flattened and subtriangular crowns, with the borders carrying serrations set more or less obliquely or parallel to the long axis of the tooth. The anterior and middle dorsal vertebræ differ from those of the *Iguanodontidæ* in having the articulation for the head of the rib forming a "step" on the transverse process, as in Crocodiles, and not a facet on the arch; while there is also no fossa between the transverse process and the postzygapophysis. The limb-bones are solid and massive; the pre- and postacetabular processes of the ilium very long; and the pubis and ischium comparatively short. The femur has an inner trochanter; the metatarsals are short and thick; and the pes, which was probably plantigrade, always has four functional digits. This family connects the *Iguanodontidæ* with the *Stegosauridæ*, and appears to be confined to the Old World, ranging from the Lias to the Cretaceous.



Fig. 1061.—Tooth of *Scelidosaurus Harrisoni;* from the Lower Lias of Dorsetshire. Twice natural size.

The type genus *Scelidosaurus*, of which a tooth is shown in fig. 1061, occurs in the Lower Lias of Dorsetshire; and is well characterised by the strongly-marked serrations of the teeth, and the short and conical dermal spines or scutes. In the Wealden, the well-known *Hylæosaurus* was a Dinosaur of considerable dimensions, characterised by its enormous and laterally-compressed dermal spines, but of which the skull and teeth are unfortunately still unknown, certain detached teeth which have been provisionally referred to it being

now known to be Sauropodous. The anterior dorsal vertebræ have a well-marked hæmal ridge, which disappears in those later in the series.

Regnosaurus is founded upon a lower jaw from the Wealden, which may pertain either to the last or the following genus. In *Polacanthus*, of the same beds, we have a remarkable form, in which the dermal armour constitutes a completely solid carapace over the whole of the dorsal aspect of the lumbar region, some of the component scutes being tuberculated, and others ridged; while there was also a number of detached flattened spines somewhat like those of *Hylæosaurus*, which probably formed a line in the dorsal region. This peculiar type of carapace forcibly recalls that of the Glyptodont Edentates. In the Chalk-Marl and Cambridge Greensand, we find *Acanthopholis* with a dermal armour somewhat similar to that of *Scelidosaurus*, but with rather more complex teeth. The smaller *Anoplosaurus*, of the Cambridge Greensand, was probably a closely allied, if not generically identical, form; while the equally small *Syngonosaurus* and *Eucercosaurus*, of the same deposits, are distinguished by their compressed and carinated dorsal vertebræ, which resemble those of *Hylæosaurus*. Apparently allied to these forms is *Vectisaurus*, of the Wealden of the Isle of Wight, originally referred to the *Iguanodontidæ*, but showing the "step" on the transverse processes of the dorsal vertebræ characteristic of the present family. *Priodontognathus*, founded on a fragment of jaw of unknown age, is probably referable to one of the preceding forms.

Family Stegosauridæ.—This family is typically represented by the genus *Stegosaurus;* but before mentioning that form it will be convenient to refer to two apparently allied Dinosaurs from the Karoo system of the Cape, both of which are very imperfectly known, and may indicate a family connecting the present with the *Iguanodontidæ*. In *Euscelesaurus* (more correctly *Euscelidosaurus*), as the first of these forms is named, the limb-bones were solid, and the femur has a large inner trochanter, and approximates somewhat to that of the Iguanodonts. The tibia and fibula seem, however, to have been more like those of the *Stegosauridæ;* being anchylosed at their two extremities, and closely joined to the astragalus and calcaneum. The caudal vertebræ, belonging either to this or the next genus, are of an Iguanodont type. The genus *Orinosaurus* (*Orosaurus*) was founded upon a bone of a larger reptile, regarded by its describer as the distal end of a femur, but which is really the proximal end of a tibia. Although solid throughout, this bone resembles the tibia of *Iguanodon* in its expanded extremity, and thus suggests a transition between the *Iguanodontidæ* and *Stegosauridæ*.

The genus *Stegosaurus* was originally described from the Upper

Jurassic of North America; but it appears that certain forms from the Oxford and Kimeridge Clays of England, described at an earlier date under the preoccupied name of *Omosaurus*, are not entitled to generic distinction. These Dinosaurs agree with the *Scelidosauridæ* in the general structure of their teeth, and the possession of a dermal armour of scutes and spines, as well as in their solid limb-bones; but differ by the great height of the neural arches of the vertebræ, as well as by the circumstance that in the sacrum each arch is either chiefly or entirely supported by a single centrum, instead of by the adjacent portions of two centra, as in the preceding families. The skull (fig. 1062) shows many points of resemblance to that of *Iguanodon*, especially in the presence of a predentary bone; but it is lower and narrower, and thereby approximates to the Scelido-

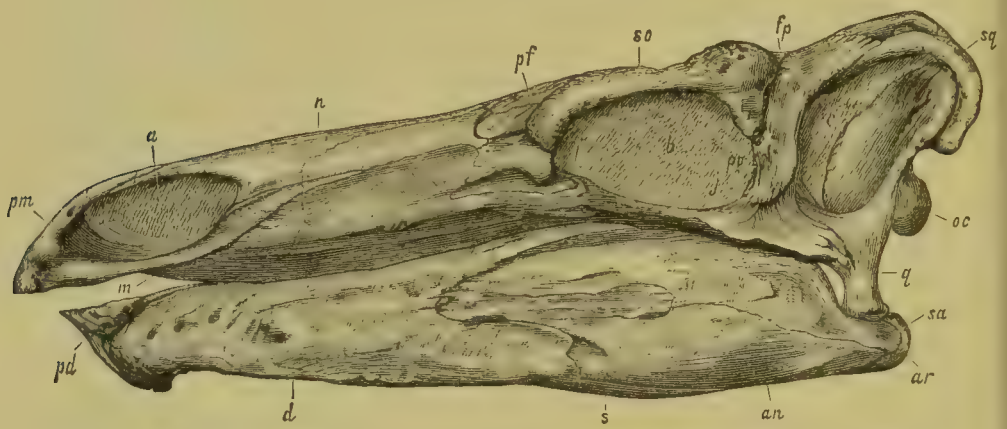


Fig. 1062.—Left lateral view of skull of *Stegosaurus stenops;* from the Upper Jurassic of North America. One-quarter natural size. *a*, Nares; *b*, Orbit; *c*, Infratemporal fossa; *pm*, Premaxilla; *m*, Maxilla; *n*, Nasal; *pf*, Prefrontal; *so*, Supraorbital; *fp*, Postfrontal; *po*, Postorbital; *l*, Lachrymal; *j*, Jugal; *q*, Quadrate; *sq*, Squamosal; *oc*, Occipital condyle; *ar*, Articular; *sa*, Surangular; *an*, Angular; *s*, Splenial; *d*, Dentary; *pd*, Predentary. (After Marsh.)

saurian type. The Iguanodont resemblance is, however, so marked as to forbid the reference of the forms with dermal armour to a separate suborder. The two rami of the caudal chevron-bones do not unite superiorly. In the pelvis (fig. 1063) the ilium has an enormous preacetabular process, and a very short postacetabular portion; while the ischium and pubis are relatively short. In the femur (fig. 1063) the inner trochanter is either very small or absent; the metatarsals are very short and stout; and the five digits of the plantigrade pes approximate in contour to those of the Elephant. The tibia and fibula are suturally united together at their extremities; and the former is completely joined to the astragalus, and the latter to the calcaneum. Other peculiar features of these remarkable reptiles are to be found in the structure of the

neural canal in the sacrum. In the solid structure and general contour of the limb-bones, as well as in the relations of the sacral centra to their arches, *Stegosaurus* approximates to the sub-order Sauropoda; and thus shows how impossible it is to bring out the true relationships of animals in a linear classification. The type species indicates a reptile about two-thirds the dimensions of *Iguanodon bernissartensis*. The American species have no inner trochanter to the femur. The name *Diracodon* has been applied to an American Jurassic type characterised by some modification in the structure of the foot. *Dystrophæus*, from the Trias of Arizona, appears to be more or less closely allied to the *Stegosauridæ*.

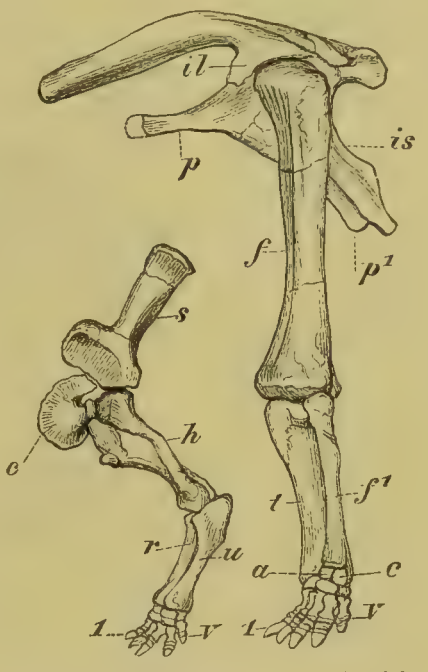


Fig. 1063.—The left pectoral and pelvic girdles and limbs of *Stegosaurus ungulatus*; from the Upper Jurassic of North America. $\frac{1}{32}$ natural size. *s*, Scapula; *c*, Coracoid; *h*, Humerus; *r*, Radius; *u*, Ulna; *i–v*, Phalangeals; *il*, Ilium; *is*, Ischium; *p*, *p*¹, Pubis; *f*, Femur; *t*, Tibia; *f*¹, Fibula; *a*, Astragalus; *c*, Calcaneum. (After Marsh.)

Family Ceratopidæ.—This name has been proposed for some remarkable Cretaceous Dinosaurs allied to the preceding family, but can only be provisionally adopted. The type genus *Ceratops* (according to Cope identical with his *Polyonax*), of the Laramie Cretaceous of the United States, carries a pair of large horn-cores on the skull, which are curiously like those of the *Bovidæ*, and were probably sheathed with horn. The body was covered with dermal scutes, which not improbably had overlying horny shields like those of Chelonians. In the Upper Greensand of Austria there occur similar horn-like bones, once thought to have been attached to the body, and described as *Struthiosaurus* (*Cratæomus*), and it has yet to be shown that the American types are generically distinct. A gigantic allied form, from the Laramie, has been christened *Triceratops*, and is characterised by the presence of an additional nasal horn-core, supported by the coalesced premaxillæ and an additional *rostral* bone. The skull is stated to be upwards of six feet in length; the frontal horn-cores measuring some 22 inches. A horn-core-like bone in the British Museum, from the Wealden, not improbably indicates an allied type.

Nodosaurus, of the Laramie, is a form more or less nearly allied to *Stegosaurus*, characterised by the completeness of the dermal armour, which consists of rows of rounded knobs, becoming small and quadrangular near the head. The skull is unknown.

Finally, the remarkable genus *Stenopelix*, from the German Wealden, should perhaps find a position somewhere in this neighbourhood, although it differs from all other members of this suborder by the presence of cavities in the centra of the caudal vertebræ.

Suborder 2. Theropoda.—The suborder Theropoda holds in some respects a position intermediate between the Ornithopoda

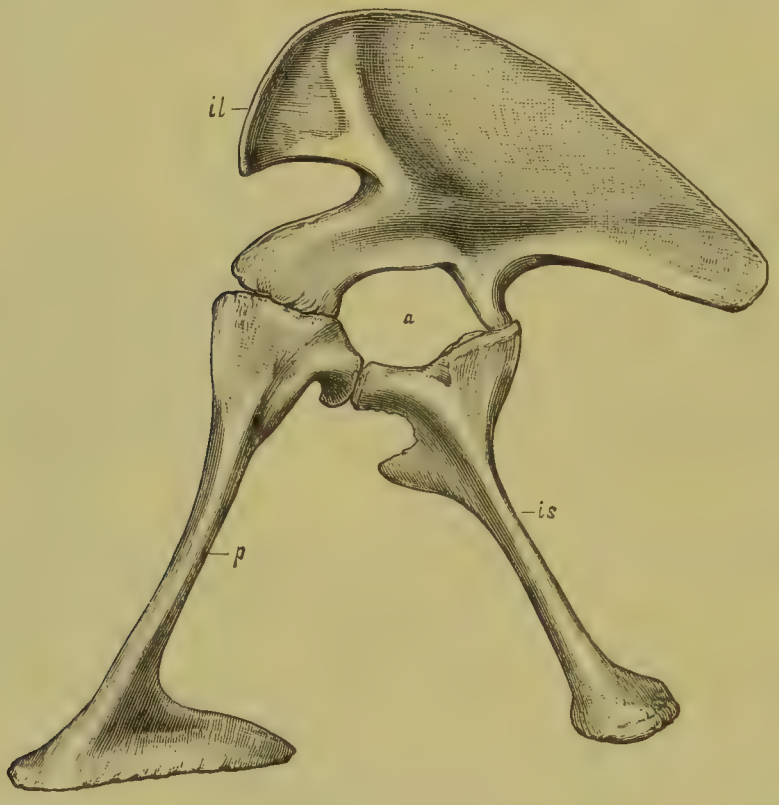


Fig. 1064.—The left side of the pelvis of *Allosaurus fragilis;* from the Upper Jurassic of North America. One-twelfth natural size. *il*, Ilium; *is*, Ischium; *p*, Pubis; *a*, Acetabulum. (After Marsh.)

and the Sauropoda, although its members are more nearly allied to the latter; with which, as already mentioned, it has been proposed to group them, under the name of Saurischia. In many respects, such as the structure of the teeth, the form of the femur, the occasional presence of only two sacral vertebræ, and the form of the quadrate bone, certain members of this suborder

make a nearer approximation than the Sauropoda to the generalised Crocodilia, although in their hollow limb-bones they agree with the higher Ornithopoda. All the forms were carnivorous. In the skull (fig. 1070) the premaxillæ are furnished throughout with teeth, which are laterally compressed (fig. 1065) and backwardly curved, with trenchant edges, of which the posterior, and frequently also the anterior, border is serrated; the directions of these serrations being generally nearly at right angles to the axis of the crown. These teeth are always implanted in distinct sockets; and the skull has a large preorbital vacuity (fig. 1070). The centra of all the vertebræ are hollowed internally; and their neural arches articulate by zygosphenes (diplosphenes) corresponding to those of the Squamata; while the centra (fig. 1067) are much compressed laterally. The limb-bones always have medullary cavities; and since the pectoral limb is much shorter than the pelvic, it is probable that many forms were of bipedal habits, although some may have been quadrupedal. In the pelvis (fig. 1064) the ilium is of great vertical depth, and has a short preacetabular process; while the pubis is directed downwards and forwards, and unites with its fellow in a long bony symphysis, which is generally extended up the anterior face of the two bones; thus causing them to have the appearance of an elongated Y, when seen from this aspect. Both the pubis and ischium are of a comparatively short and slender type of structure, and the latter usually has an obturator process like that of the Ornithopoda. The astragalus is usually closely applied to the tibia, and not unfrequently gives off a long flattened process lying on the anterior face of the latter bone, and thus resembles the condition found in young Ratite Birds before the anchylosis of the two bones has taken place. The metatarsals are elongated, and the feet digitigrade. In the manus the number of the digits varies from four to five; while in the pes there may be either three or five. And in all cases their terminal phalangeals are furnished with curved claws, which in the manus are very long and prehensile, and were apparently adapted for the seizure and retention of the living prey.



Fig. 1065.—Lateral aspect of a tooth of *Megalosaurus Bucklandi*; from the Stonesfield Slate. One-third natural size.

It may further be observed that while the cervical vertebræ are frequently shorter than the dorsals, as in the Ornithopoda, yet they are sometimes longer, like those of the Sauropoda; while the vertebral arches in the sacrum are occasionally supported by single centra, as in the latter. Finally, the femur, which may be either somewhat longer or shorter than the tibia, is generally of a more Crocodilian type—especially shown in its flattened head—than in

any other Dinosaurs, although it has a distinct inner trochanter. In all cases the dorsal vertebræ are amphicœlous.

Family Anchisauridæ.—The least specialised forms constituting this family, of which the name must be considered provisional, are mainly known from beds of Triassic age, and are typically represented by the North American genus *Anchisaurus* (*Amphisaurus*). The cervical vertebræ are amphicœlous; the pubes are slender rod-like bones; and there are five digits in both the manus and the pes. The teeth (fig. 1066) usually have comparatively thick and short crowns, with a slightly convex posterior border, and more or less oblique serrations, which occupy the whole of both borders. *Thecodontosaurus* occurs in the Lower Keuper near Bristol; the teeth of the type species being much smaller than the one figured in the woodcut. *Anchisaurus* (which, according to Professor Marsh, is identical with a form described at an earlier date under the preoccupied name *Megadactylus*) occurs in the reputed Trias of the United States; but no evidence has yet been presented to show how it differs from the European genus. The writer last quoted includes in this family the American Triassic genera *Bathygnathus* and *Clepsysaurus*, both of which are still very imperfectly known. Here may be mentioned the genus *Massospondylus*, from the Karoo system of South Africa and the Maleri stage of the Gondwana system of India, of which a tooth is shown in fig. 976 (p. 1049), and the centrum of a dorsal vertebra in fig. 1067. These vertebræ approximate to those of *Megalosaurus*, and have a fusiform internal cavity.



Fig. 1066.—Outer aspect of the crown of a tooth of *Thecodontosaurus platyodon*; from the Lower Keuper near Bristol.



Fig. 1067.—Lateral and inferior aspects of the centrum of a dorsal vertebra of *Massospondylus carinatus*; from the Karoo system of Basutoland. One-half natural size.

Finally, it is highly probable that an amphicœlous cervical vertebra obtained from beds of unknown Mesozoic age in Bathurst Island, Arctic America, and described under the name of *Arctosaurus*, indicates a Dinosaur more or less closely allied to the present or following family. This vertebra agrees approximately in size with that of *Calamospondylus* (fig. 1071), but has free cervical ribs and a neural spine; the length and curvature of the

centrum being indicative of a long and arched neck. The occurrence of a Dinosaur so far north is of extreme interest, as serving to show how genera common to the Old and New Worlds may have migrated from the one hemisphere to the other.

Family Megalosauridæ.—In this family the cervical vertebræ are (when known) shorter than the dorsals, and may be either amphi- or opisthocœlous; while the dorsals often have prominent ridges at the base of the arches, between which are deep pits; the vertebral centra, as in the last family, having a fusiform internal cavity. In the pelvic limb of the type genus, the femur is of a remarkably Crocodilian type, and is longer than the tibia. The crowns of the teeth (fig. 1065) are more or less tall, and much compressed, with the posterior border distinctly concave, and the serrations, which are nearly at right angles to the axis of the crown, usually wanting at the lower part of the anterior border. In the Lower Keuper of England we meet with *Palæosaurus* (with which *Cladyodon* of the same deposits may be identical), of which only detached teeth are known. In the Upper Keuper of the Continent there occurs the comparatively generalised genus *Zanclodon* (*Teratosaurus*), which is not improbably identical with *Plateosaurus*, in which case the latter name should be adopted. The serrations on the anterior borders of the crowns of the teeth continue nearly to the base; the cervical vertebræ are amphicœlous; there are but two vertebræ in the sacrum; and the astragalus does not give off a process ascending on to the anterior surface of the tibia. One of the species was fully as large as *Megalosaurus*, and the genus was probably represented in the Lower Lias of Dorsetshire. The small *Epicampodon* (*Ankistrodon*), of the Panchet stage of the Indian Gondwanas, has teeth (fig. 1068) of a Megalosauroid type, in which the serrations are totally absent from the anterior border, and do not extend to the base of the posterior border.

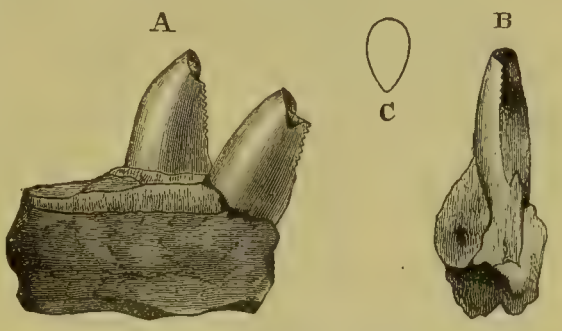


Fig. 1068.—Fragment of the mandible of *Epicampodon indicus*; from the Panchet beds of the Gondwanas. Three times natural size. A, Lateral; B, Posterior aspect; C, Transverse section of tooth. (After Huxley.)

The type genus *Megalosaurus* has been rendered classic through the labours of the late Professors Buckland and Phillips, and affords an excellent and instructive instance of the gradual restoration of the skeleton of an extinct and uncouth form from more or less fragmentary remains. In Europe this genus ranges from the Stones-

field Slate (Lower Jurassic) of England to the topmost Cretaceous of Maastricht in Holland; and has also been recorded from the Upper Cretaceous of Southern India. There is good evidence of the existence of two species in the Wealden. An attempt at a restoration of the skeleton of the type species is shown in the accompanying woodcut. The North American *Allosaurus* (of which the pelvis is represented in fig. 1064) appears to be a closely allied form of Upper Jurassic age. The nearly entire skeletons of the latter and other American forms have shown that certain very excusable errors were made in the restoration of the imperfect elements of the skeleton of the English genus; and it is quite evident that the skull of *Megalosaurus* must have had an inferior temporal arcade, and that it approximated more or less closely to that of *Ceratosaurus* (fig. 1070), although the bony processes of the latter may have been wanting. In the teeth (fig. 1065) the serrations on the anterior border are in

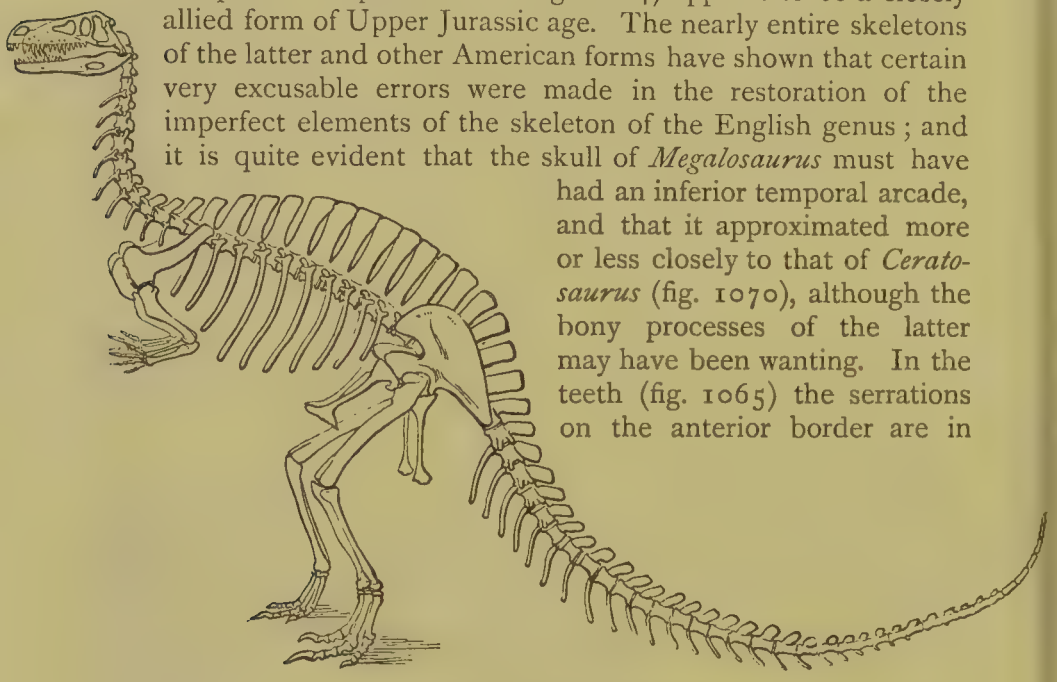


Fig. 1069.—Restoration of the skeleton of *Megalosaurus Bucklandi*; from the Stonesfield Slate. Greatly reduced.

some cases confined to the upper half of the crown, but in others extended nearly throughout. Typically there are five vertebræ in the sacrum; the cervical vertebræ are opisthocœlous; the astragalus has a process ascending on to the tibia; and there were three digits in the pes and probably four in the manus. In the North American *Creosaurus* we have an allied Upper Jurassic genus, in which the postcervical vertebræ have very deep depressions on the sides of their centra; and there are but two sacral vetebræ. In *Ceratosaurus*, of the Upper Jurassic of North America, the skull (fig. 1070) is remarkable for carrying a single bony protuberance behind the terminal nares, and a pair of similar protuberances directly in advance of the orbits; while the mandible has a lateral vacuity like that of the Crocodilia. Professor Marsh believes that the protuberances on the skull supported horns. In the type specimen the three pelvic bones and the metatarsals were respectively anchylosed

together; but this may perhaps be due to a pathological peculiarity of the individual. This genus is regarded by its describer as the type of a distinct family—the *Ceratosauridæ*. Here may be mentioned a small and imperfectly known Dinosaur from the Wealden for which the name *Aristosuchus* has been proposed. The type specimen comprises the sacrum and part of the pelvis. It is considered by its describer that the sacrum includes five vertebræ, while the pelvic bones, which have a long ventral symphysis, were originally described as pubes, although it has been subsequently suggested that they may be ischia. The dorsal vertebræ referred to this form by Sir R. Owen have a fusiform internal cavity in the centrum, but it has been recently suggested that this reference is

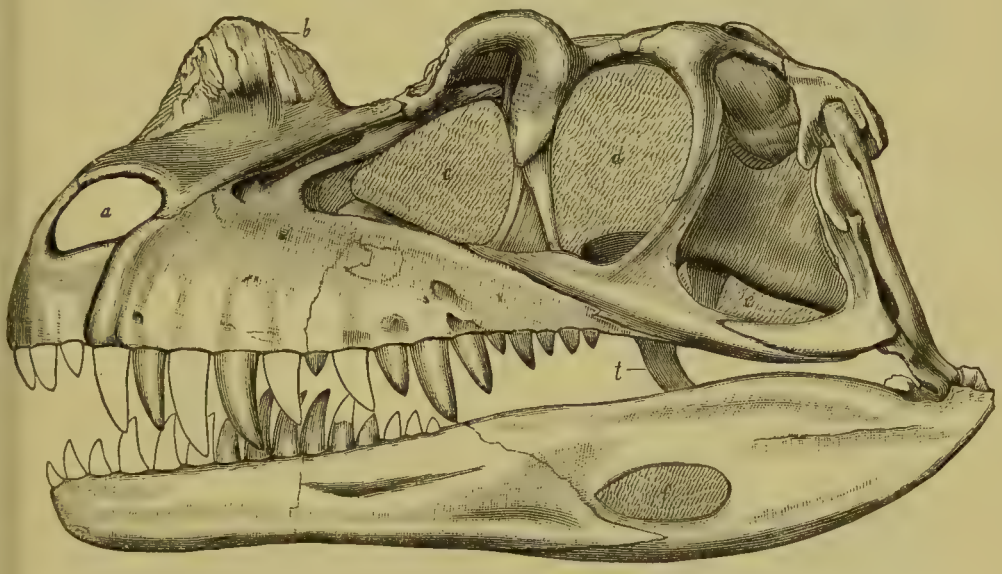


Fig. 1070.—Left lateral view of skull of *Ceratosaurus nasicornis*; from the Upper Jurassic of North America. One-sixth natural size. *a*, Nares; *b*, Bony prominence; *c*, Preorbital vacuity; *d*, Orbit; *e*, Infratemporal fossa; *f*, Mandibular vacuity; *t*, Transverse bone. (After Marsh.)

incorrect, and that this genus may have had dorsal vertebræ like those of the *Cœluridæ*, in which case this form may be referable to *Cœlurus*, in which, indeed, it has been placed by Professor Marsh.

Family Compsognathidæ.—This family is represented by the small *Compsognathus* of the Lower Kimeridgian Limestone of Bavaria, and the allied or identical *Hallopus* of the Upper Jurassic of North America. In the typical genus—known only by a single skeleton—the cervical vertebræ are opisthocœlous, and much longer than the amphicœlous dorsals, and have free cervical ribs. In the limbs the femur is shorter than the tibia, and both the manus and

pes have only three functional digits; the astragalus being closely applied to the tibia. The teeth and pelvis approximate to the Megalosaurian type. *Compsognathus* was about two feet in total length; and undoubtedly hopped on its pelvic limbs, after the manner of a bird. *Hallopus* is one of the few Dinosaurs with only two sacral vertebræ; the number of those of *Compsognathus* being unknown.

Family Cœluridæ.—This family is represented by comparatively small forms, ranging in size from five or six to about twelve feet in length. They are characterised by the vertebræ and ribs being completely honeycombed by cavities, communicating with a small aperture on the side of the centrum. The cervical vertebræ (fig. 1071) are typically longer than the dorsals, and have the ribs anchylosed to the arch and centrum, and the neural spine reduced to a mere ridge. The limb-bones are hollow, and the pelvis is of

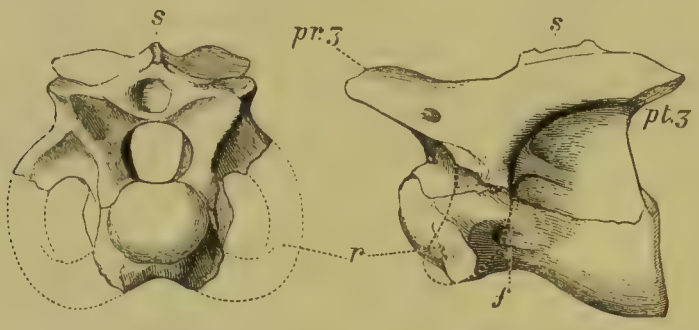


Fig. 1071.—Anterior and left lateral aspects of a cervical vertebra of *Calamospondylus Foxi*; from the Wealden of the Isle of Wight. Two-thirds natural size. *prz*, Prezygapophysis; *ptz*, Postzygapophysis; *r*, Rib (restored); *f*, Pneumatic foramen; *s*, Neural spine.

the ordinary Theropodous type, with a very long pubic symphysis. The type genus *Cœlurus*, typically from the Upper Jurassic of America, but also occurring in the English Wealden, has the cervical vertebræ greatly elongated, the first few being opistho- and the remainder amphicœlous. In *Calamospondylus* (fig. 1071) the cervicals were shorter, and were probably all opisthocœlous; the one known species being from the English Wealden. Professor Cope includes in this family other small Dinosaurs from the Trias of North America, which he identifies with *Tanystrophæus*, originally described on the evidence of extremely elongated caudal vertebræ from the German Muschelkalk, once referred to the Sauropterygia. In these forms all the cervical vertebræ were amphicœlous; and the femur has an inner trochanter. *Megadactylus*, which Professor Cope regards as identical with these forms, is, as already mentioned, identified by Professor Marsh with *Anchisaurus*.

Suborder 3. Sauropoda.—With the third and last suborder we

enter upon the consideration of the largest known Dinosaurs, and those which make so many marked approximations to the more generalised Crocodilia as to show how close is the relationship between that order and the Dinosauria.[1] The skull (fig. 1076) agrees with that of the Theropoda in having the premaxillæ completely toothed, and also in the presence of a large preorbital vacuity; but the external nares formed long slits in the fore part of the skull as in Ornithosaurs and Birds. The teeth are invariably set in distinct sockets and are of a spatulate form, without marginal serrations (fig. 1072). The sternal bones are ovate. All the vertebræ in advance of the sacrum, and sometimes those of that region also, have a large vacuity on each side of the centrum communicating with a series of internal cavities, which give a honeycomb-like structure to the whole vertebra. This affords a combination of strength and lightness in the massive supports necessarily required for the huge ribs, limbs, and muscles, which could not have been attained in any other manner. All the anterior vertebræ are opisthocœlous; and in the cervical region the ribs are anchylosed to the vertebræ, which have no neural spines, and are longer than the dorsals; while the spines of the latter are laterally expanded; and in the sacrum each centrum supports its own arch. The limb bones are solid; and since the pectoral limb is not much shorter than the pelvic, it appears that these Reptiles were habitually quadrupedal. All the feet were plantigrade, and furnished with five digits; those of the pes being terminated by large curved claws. The ilium (fig. 1073) has its upper border only moderately arched and its postacetabular portion short; while the pubis (fig. 1073), which is directed downwards and forwards, is stout with a comparatively small distal expansion, where it unites by a cartilaginous symphysis with its fellow of the opposite side. The ischium (fig. 1073) is likewise a stout bone agreeing with that of the Crocodilia in the absence of an obturator process; and the two ischia have a peculiar incurving of their distal extremity where they meet in a symphysis.

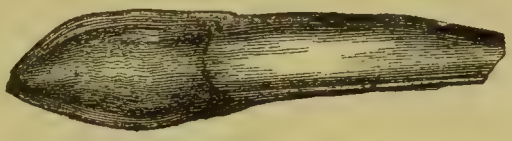


Fig. 1072.—Outer side of a tooth of *Morosaurus grandis*; from the Upper Jurassic of North America. One-half natural size. (After Marsh.)

It may be observed that in the lateral views of the pelvis shown in the figures, where the bones are drawn more or less nearly in a vertical plane, it is impossible to give a true idea of the peculiar contour of the distal extremity of the pubis and ischium. These bones are really concave from above downwards on the outer (figured) aspect, and convex on

[1] Professor Cope would include the Sauropodous Dinosaurs in the Crocodilia.

the inner aspect; and owing to a confusion between the proper inner and outer sides of the English specimens, only recently cleared up, it has been considered by some palæontologists that there was an essential difference between the structure of the pelvis of the English and American forms.

The femur in its straight shaft and absence of an inner trochanter likewise resembles to a considerable extent that of the Crocodilia;



Fig. 1073.—The left side of the pelvis of *Brontosaurus excelsus;* from the Upper Jurassic of North America. One-sixteenth natural size. *a*, Acetabulum; *il*, Ilium; *is*, Ischium; *p*, Pubis; *f*, Foramen in do. (After Marsh.)

although its head is not laterally compressed to the same extent, nor placed so obliquely to the distal condyles.

In time this suborder ranges from the Upper Trias to the Cretaceous, and it is especially well represented in the Kimeridge Clay and Wealden of Europe.

Family Atlantosauridæ.—This name may be provisionally adopted for a family which is represented by the genera *Atlantosaurus*, *Apatosaurus*, and *Brontosaurus*, of the Upper Jurassic of North America, as well as by allied European types. In these huge forms the ischium (fig. 1073) is directed downwards, and its shaft is thick and not bent upon itself; while the humerus is comparatively slender; and the chevrons of the caudal vertebræ have their superior extremities united. The teeth have the summit of the crown not

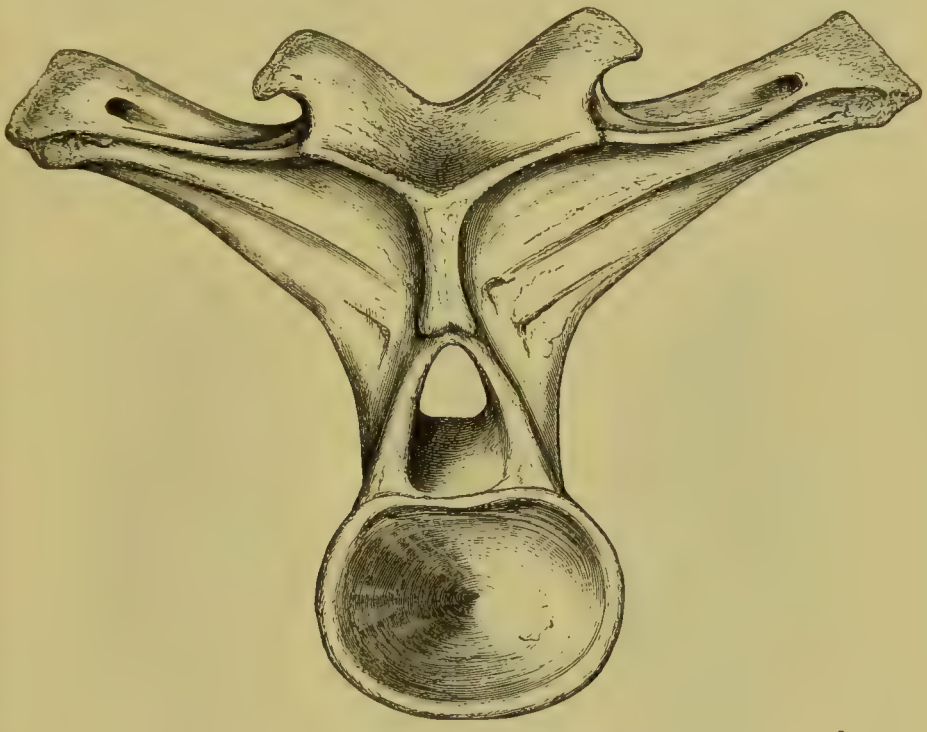


Fig. 1074.—Posterior view of an anterior dorsal vertebra of *Camarasaurus supremus*; from the Upper Jurassic of North America. Reduced. (After Cope.)

much incurved. Apparently closely allied to, if not identical with, some of the above-mentioned genera are *Amphicœlias* and *Camarasaurus* of the same formations. An anterior dorsal vertebra of the latter genus is represented in the accompanying woodcut; this vertebra is transitional between the cervicals and later dorsals, the neural spine of the latter being absent.

Professor Marsh estimates the total length of *Brontosaurus* at upwards of fifty feet, and its weight at more than twenty tons; and *Pelorosaurus*, of the English Wealden, must have been fully equal to these dimensions. In respect of the former, the learned American palæontologist observes, "that the animal at times assumed a more erect position than is represented in the restoration is probable, but locomotion on the posterior

limbs alone was hardly possible. The head was remarkably small. The neck was long, and, considering its proportions, flexible; and was the lightest portion of the vertebral column. The body was quite short, and the abdominal cavity of moderate size. . . . Each footprint must have been about a square yard in extent. The tail was large, and nearly all the bones were solid. The diminutive head will first attract attention, as it is smaller in proportion to the body than in any vertebrate hitherto known. The entire skull is less in diameter or actual weight than the fourth or fifth cervical vertebra. . . . The very small head and brain, and slender neural cord, indicate a stupid, slow-moving reptile. The beast was wholly without offensive or defensive weapons, or dermal armature. In habits, *Brontosaurus* was more or less amphibious, and its food was probably aquatic plants or other succulent vegetation. The remains are usually found in localities where the animals had evidently become mired."

Of still more stupendous bulk is *Atlantosaurus immanis*, the femur of which has the enormous length of six feet two inches, and thus

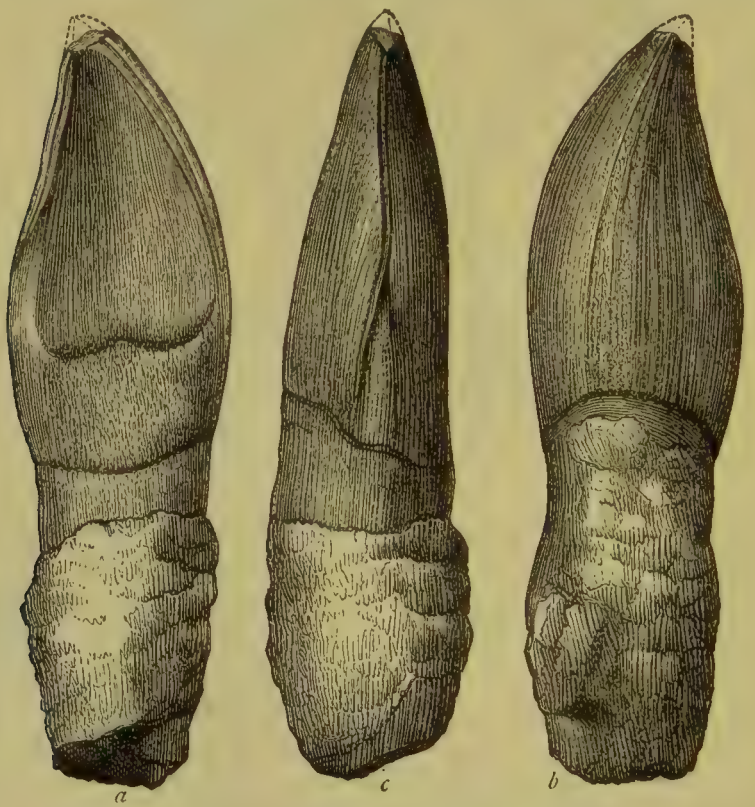


Fig. 1075.—Inner (*a*), outer (*b*), and profile (*c*) views of a tooth of *Hoplosaurus armatus*; from the Wealden of the Isle of Wight. (After Wright.)

indicates one of the largest land animals yet known; the only form which could possibly have exceeded it being the Cretaceous *Triceratops* mentioned above. It is by no means clear that all these

American types are generically distinct from those to be now mentioned.

We may now proceed to the consideration of certain European Dinosaurs which from their more or less close alliance to the preceding forms appear to belong to the same family, although opinions to the contrary have been expressed. It may be observed in this connection that the study of all the European Sauropoda is beset with almost insurmountable difficulties owing to the circumstance that nearly all the specimens are disassociated, and that genera and species have been named on the evidence of single teeth, vertebræ, or bones of the limbs or limb-girdles, so as not to admit of comparison with one another. Moreover, the unwieldy bulk of the specimens themselves is a bar to an exact comparison, even when they are strictly comparable one with another.

The tooth from the Wealden of the Isle of Wight, represented of the natural size in fig. 1075, has been made the type of the genus *Hoplosaurus* (*Oplosaurus*), and it appears almost certain that cervical and dorsal vertebræ, and a pelvis from the same deposits, described under the names of *Ornithopsis Hulkei* and *O. eucamerotus*, are referable to the same form. These remains indicate a Reptile of considerably smaller dimensions than *Brontosaurus*, having a pelvis which approximates in structure to that of *Atlantosaurus*. The ischium, which has the downward direction characteristic of the present family, has a length of 27 inches, and is comparatively wide in proportion to the pubis. The genus *Pelorosaurus* is typified by a huge humerus from the Wealden of Sussex, measuring some 54 inches in length, which would appear far too large for the type species of *Hoplosaurus*.[1] A slightly larger humerus from the Kimeridge Clay, originally described as *Cetiosaurus humerocristatus*, appears generically inseparable from *Pelorosaurus*, and its owner was in all probability very closely allied to an equally large form from the Oxford Clay, described upon the evidence of the pelvis as *Ornithopsis Leedsi*. Of the latter the lumbar and caudal vertebræ are also known, and approximate closely, both in size and contour, to those of *Brontosaurus*, the lumbars having a diameter of nearly 12 inches across the centrum. In the pelvis the ischium measures nearly 36 inches in length, and is also narrower in proportion to the pubis than in *Hoplosaurus*—differences which, coupled with others, may probably be regarded as of generic value. Referring all these forms, at least provisionally, to *Pelorosaurus*, it would appear that this genus includes very large *Dinosaurs* closely allied both in vertebral and pelvic characters, as well as in point of size, to *Brontosaurus*, al-

[1] Compare the proportions of this bone and of the ischium mentioned below with the corresponding dimensions of other Dinosaurs given in the table on the next page.

though it is probable that the humerus was relatively longer. Teeth from the Kimeridgian of Boulogne, upon the evidence of which the genus *Neosodon* was founded, but which were subsequently identified with American forms described as *Caulodon*, are probably referable to the same species. Small vertebræ from the Kimeridge Clay of Swindon, upon which the genus *Bothriospondylus* was established, may perhaps be referable to a very young individual of *Pelorosaurus humerocristatus;* while a comparatively small humerus from the same deposits, originally described under the preoccupied name of *Ischyrosaurus*, may indicate a smaller species of the same genus. Finally, of the Kimeridgian remains described as *Gigantosaurus*, while some may be referable to *P. humerocristatus*, a sacral vertebra may belong to the smaller *P. Manseli* above mentioned.

The following table gives the dimensions of some of the bones of certain of the above-mentioned forms, together with those of others noticed below under the head of the *Cetiosauridæ*:—

	Atlantosaurus.	*Brontosaurus.*	*Pelorosaurus Conybeari.*	*Pelorosaurus humerocristatus and Leedsi.*	*Hoplosaurus.*	*Morosaurus* (type).	*Cetiosaurus.*	*Morosaurus brevis.*
Length of scapula . .	...	60	...	...	...	45	54	...
" humerus . .	...	50?	54	57	...	36	51.5	24
" ischium . .	...	40	...	35.5	27	30.5	39?	...
" femur . .	74	70?	...	...	...	46	64	...
Width of dorsal centrum .	...	13	...	...	8.5	...	...	6
" lumbar " .	...	14	...	11.5[1]	...	...	...	7
" caudal " .	...	12	...	...	...	...	?10	7

Family Diplodocidæ.—The genus *Diplodocus*, from the Upper Jurassic of North America, is typically represented by a species of smaller size than many of the preceding forms, and is regarded by Professor Marsh as the type of a family. It was originally considered that the external nares were single, and situated at the top of the skull between the orbits (fig. 1076); but it now appears that they really formed long narrow slits between the premaxillæ, nasals,

[1] Caudal vertebræ of a larger individual are nearly equal in size to those of *Brontosaurus*.

and maxillæ, after the fashion obtaining in Pterodactyles and Birds. And it is probable that a similar arrangement exists in the other members of the suborder. It will be observed from the figure that the jugal bifurcates posteriorly to form the anterior and inferior borders of the orbit; while the quadratojugal joins the maxilla without the intervention of the jugal, which is thrust up. These peculiar features are repeated, as will be noticed below, in one genus of the Ornithosauria. The pelvis is of the general type of

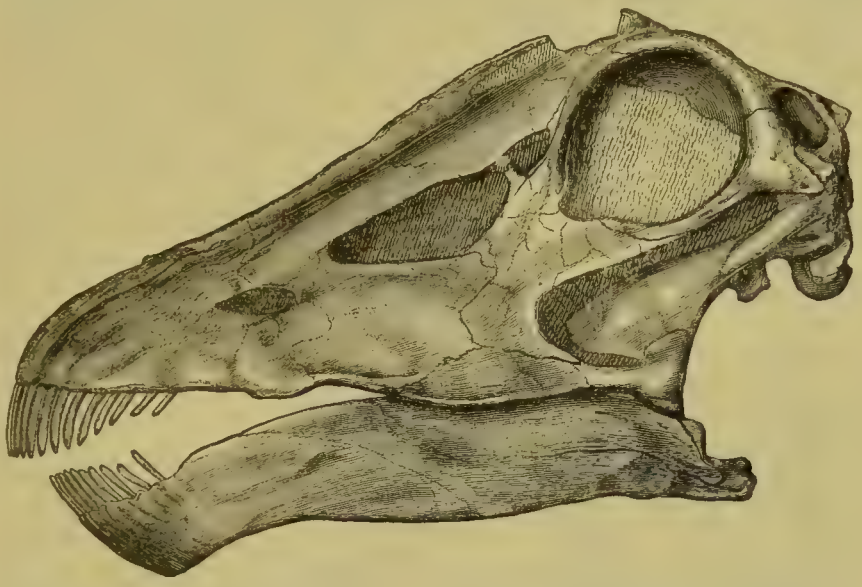


Fig. 1076.—Left lateral aspect of the skull of *Diplodocus longus*; from the Upper Jurassic of North America. One-sixth natural size. The position of the nares at the top of the skull is incorrect. (After Marsh.)

that of the last family; but the distal extremity of the ischium is not expanded.

Family Cetiosauridæ.—This family is typically represented by the English genus *Cetiosaurus*, which, so far as can be determined from the characters of the scapula and pelvis, appears to be so nearly related to the American *Morosaurus* that there seems every reason for including the latter in the same family. *Cetiosaurus* occurs typically in the Lower Jurassic Great Oolite, and Forest-Marble of Oxfordshire and Northamptonshire, where we meet with the huge *C. oxoniensis*. Comparatively small teeth from the same deposits, described under the earlier name of *Cardiodon rugulosus*, are of the same general type as those of *Hoplosaurus*, but have relatively smaller crowns, with a more incurved summit, and are clearly distinct from the last-named genus. Professor Phillips referred teeth of this type to *C. oxoniensis*, but from their small size they

would agree better with a dorsal vertebra from the same deposits subsequently described as *Bothriospondylus robustus*. This vertebra is somewhat longer than the dorsals of *C. oxoniensis*, but need not be generically distinct. In *Cetiosaurus* the caudal vertebræ have no distinct postzygapophyses, and articulate by two facets with the chevrons, of which the upper extremities are not united, as in Crocodiles. The scapula is much expanded at its distal extremity, and the humerus, though long, is wider and shorter than in the European forms mentioned among the *Atlantosauridæ*. The ischium appears to be of the same general type as that of *Morosaurus* (fig.

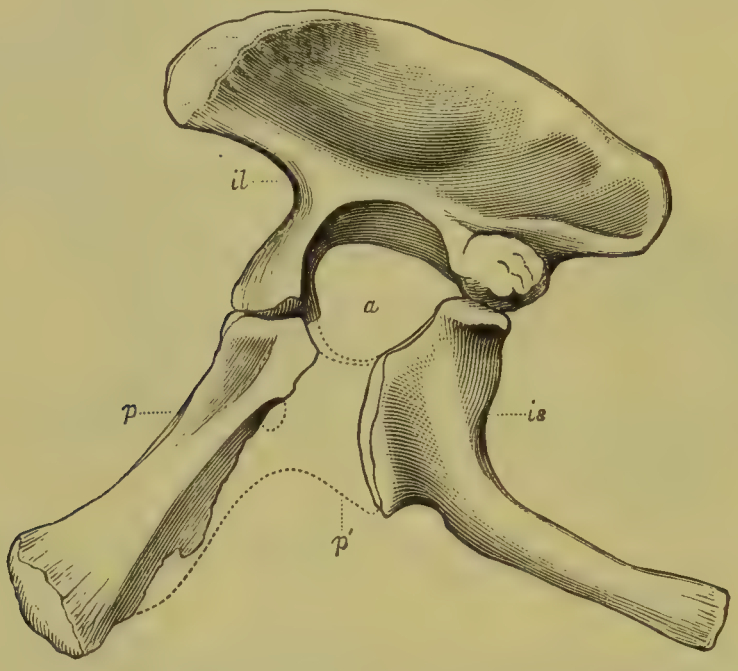


Fig. 1077.—The left side of the pelvis of *Morosaurus grandis*; from the Upper Jurassic of North America. One-sixteenth natural size. *a*, Acetabulum; *il*, Ilium; *is*, Ischium; *p*, *p'*, Pubis. (After Marsh.)

1077), in which the shaft is bent backwards and has no distal expansion, while the symphysis does not extend to the extremity; thus causing the middle of the acetabular part to be far above the axis of the shaft.

The typical species of *Cetiosaurus* is comparatively well known through the labours of the late Professor Phillips. This huge reptile was perhaps somewhat smaller than *Pelorosaurus*; and it was inferred from the well-ossified extremities of the limb-bones, the free projection of the head of the femur into the acetabulum, and the large terminal claws, that this creature was of terrestrial or subaquatic habits, and that it probably dwelt on the banks of lakes or rivers among brakes of ferns, cycads, and conifers. From the structure of a tooth (*Cardiodon*) found in the same

beds, the Cetiosaur was inferred to have been of herbivorous habits. How remarkably these conclusions have been confirmed by the discovery of the allied American forms, is now a matter of history.

In the Wealden sacral and caudal vertebræ of the general type of those of *Cetiosaurus*, described under the name of *Cetiosaurus brevis*, indicate a smaller form than *Hoplosaurus*. It is probable that a dorsal vertebra from the same deposits, described as *Bothriospondylus elongatus*, as well as a humerus and other bones of the pectoral limb, to which the name *Morosaurus Becklesi* has been applied, are referable to the same form, which would appear to be generically distinct from *Cetiosaurus*, and may be known as *Morosaurus brevis*. The dimensions of some of the bones are given in the table on p. 1176. An ilium, from the same beds, closely resembles that of the American genus, and probably belongs to the same form. In North America, *Morosaurus* and the small *Pleurocœlus* are characteristic of the Upper Jurassic. The dorsal vertebræ of the latter are relatively elongated, and do not exceed five inches in length; those of one species being remarkable for their very low neural arches. Small teeth from the Wealden (fig. 1078), once referred to *Hylæosaurus*, probably belong to a species of *Pleurocœlus*. These teeth are less spoon-shaped, and approximate more to a compressed cone than those of *Morosaurus* (fig. 1072); and the genus *Pleurocœlus* includes the smallest representatives of the suborder. The pelvis of *Morosaurus* is shown in fig. 1077; the teeth (fig. 1072), although considerably larger than those of *Cardiodon* and *Pleurocœlus*, exhibit the same incurving of the crown.



Fig. 1078. — Outer and profile views of a tooth of *Pleurocœlus valdensis*; from the Wealden.

In the preceding forms the centra of the caudal vertebræ are amphicœlous; but *Titanosaurus*, originally described from the Cretaceous of India, and subsequently found in the English Wealden and Upper Greensand, has procœlous centra to these vertebræ. The femur of this genus indicates an animal as large as *Cetiosaurus*.

Remains of other Cretaceous Sauropoda have received distinct generic names, but some of them may be identical with the above-mentioned types. Thus we have *Dinodocus* based on broken bones from the Lower Greensand of Kent; and *Æpysaurus* founded on a humerus from the French Cretaceous. *Macrurosaurus*, from the Cambridge Greensand, is a smaller form, with imperfectly procœlous caudal vertebræ. Finally, the name *Thecospondylus* has been applied to a specimen from the Wealden, of which even the subordinal position cannot be determined, although it has been suggested,

without sufficient foundation, that it indicates a form allied to *Cœlurus*.

Order IX. Crocodilia.—The Crocodiles of the present day are well-known, lacertiform Reptiles inhabiting the lakes, rivers, and marshes of the warmer regions of the globe; and are the largest existing representatives of the entire class. If we had only these existing and specialised forms to deal with, we should have no difficulty in giving a concise definition which would separate the order to which they belong from the Dinosauria. There occur, however, in the Trias a number of generalised forms which approximate so closely to the latter order as to render such definition extremely difficult; and it is quite possible that some of the undermentioned characters are not applicable to the first suborder. The order is sometimes known as the Emydosauria.

In all the forms the limbs and body (fig. 1079) are of a lacertiform type, the former being very short, and the latter long and

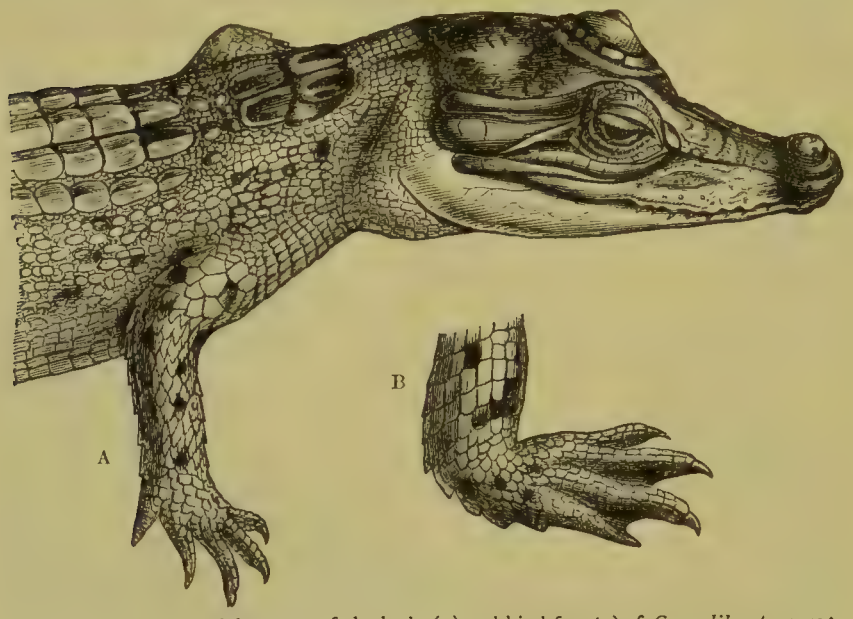


Fig. 1079.—Head and fore-part of the body (A) and hind foot (B) of *Crocodilus porosus*; from Madras. Much reduced. (After Günther.)

carried close to the ground; while the tail is relatively long. With the exception of a few later Jurassic forms, the dorsal aspect of the body carries a dermal armour of articulating or imbricating bony scutes, arranged in two or more longitudinal rows (fig. 1079), and marked on their outer surface by a series of deep pits. In certain cases there may also be an armour of similar type developed on the ventral surface of the body. The centra of the vertebræ are either amphi- or procœlous, and the neuro-central suture is persistent.

The cervical vertebræ have double pedunculate costal tubercles, situated one on the centrum and the other on the arch; and the cervical ribs have long processes projecting anteriorly and posteriorly, which completely prevent the head from being turned sideways. In the dorsal region usually the four anterior vertebræ have the transverse process for the articulation of the tubercle of the rib placed on the arch, while there is a lower process, or rib-facet, on the centrum for the capitulum of the rib; but posteriorly this rib-facet rises on to the arch, and in the middle dorsals forms a kind of "step" on the transverse process, while still more posteriorly it merges with the tubercular facet. The dorsal ribs have uncinate processes, like those of Birds; and the chevron-bones of the caudal region usually have the upper limbs of the Y not united



Fig. 1080.—Oblique left lateral and superior view of the skull of *Crocodilus palustris*; India. Much reduced. The small paired apertures to the right are the supratemporal fossæ, in advance of which are the orbits communicating posteriorly with the infratemporal fossæ.

by bone. Normally the sacrum has but two vertebræ.[1] The skull (fig. 1080) is relatively large in proportion to the body, and is usually much depressed; its component bones are firmly united, and generally have a characteristic sculpture on their external surface. The palatines and pterygoids unite in the middle line, and thus close the palate; and very frequently one or both of these paired bones develop inferior plates, which meet beneath the narial passages (fig. 1089). The quadrate is tightly wedged in among the adjacent bones; the tympanic cavities usually communicate with the mouth by three eustachian canals; the mandibular symphysis unites by suture; and there are generally no ossifications in the sclerotic of the eyeball. There is almost invariably a lateral vacuity in the mandible (fig. 1093). The teeth are always either pointed

[1] As an abnormality three sacrals may be present.

and subconical, or laterally compressed. In the sternal region the sternum itself is cartilaginous; and there is a bony interclavicle, but generally no clavicle. In the pelvis (fig. 1081) the ilium is short and deep, without distinct preacetabular or pubic processes; the ischium is stout, and devoid of obturator process; while the pubis[1] is directed downwards and forwards, and is frequently excluded from the acetabulum. In regard to the pectoral girdle and limbs, it will suffice to say that all the bones are solid; that the coracoid has a fontanelle, and may be either short or long; that in the humerus and femur the heads are imperfectly differentiated, that of the latter being compressed and placed very obliquely to the plane of the condyles; while the shaft of the femur has no inner trochanter. Moreover, the tibia has no cnemial crest at its proximal extremity. The habits of all the members of the order are quadrupedal; and the feet (fig. 1079) are plantigrade, those of the hind limbs being partially webbed.

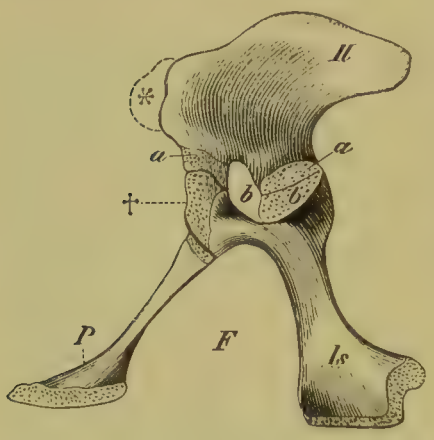


Fig. 1081.—Left side of the pelvis of a young *Alligator*. *Il*, Ilium; *Is*, Ischium; *P*, Pubis; *a*, *b*, *b*, Acetabulum, with its vacuity; *F*, Obturator notch; †, *, Cartilaginous processes of the ischium and ilium.

The existing Crocodiles present many peculiarities in regard to the soft parts; but since we do not know whether the same features occurred in the generalised fossil forms, and cannot compare them with extinct orders, it is unnecessary to allude to them further.

This order is peculiarly interesting, not only as containing the on y existing members of the Archosaurian branch; but also since it affords a beautiful example of the gradual evolution of specialised characters as we ascend in the geological scale.

Suborder 1. Aëtosauria.—This provisional suborder includes but a single family, which Dr Baur places in the Crocodilia, although Professor Cope regards it as more nearly related to the Rhynchocephalia, to which it perhaps belongs.

Family Aëtosauridæ.—This family is typically represented by the genus *Aëtosaurus*, of the Upper Trias of Würtemberg; a small form with Crocodilian armour and limbs, but with the metatarsals much elongated, and approaching in many points of its organisation to the Theropodous Dinosauria, to which Professor Marsh regards

[1] It has been suggested that the bone termed pubis in the Eusuchia is really a prepubis.

it as nearly related. *Typothorax*, with pitted scutes adherent to the ribs, is an allied form from the reputed Trias of North America; which Professor Cope regards as foreshadowing in its dermal skeleton the carapace of the Chelonia.

Suborder 2. Parasuchia.—This extremely generalised suborder is confined to the Trias, or strata of approximately equivalent age. It is characterised by the absence of descending palatal plates developed from the roof of the mouth, so that the posterior nares (fig. 1083) open directly into the latter, without the intervention of a secondary passage. The vomers are seen on the palate; the middle one of the three eustachian canals appears to be wanting[1]; the anterior nares are placed in the middle of the cranium; and the premaxillæ have typically some twenty-one teeth, and are produced into a long rostrum. A clavicle was probably present, the coracoid was short and rounded like that of the Dinosauria; while the pubis, as in the latter, takes a share in the formation of the acetabulum; and each foot was probably furnished with five digits. The centra of the vertebræ are amphicœlous; and the dorsal scutes have a keel-like ridge, and form only two longitudinal rows; while those of the ventral buckler (when present) are arranged in not more than eight of such rows, and each scute consists of a single bone. This group differs very widely from the true Crocodiles, and Dr Baur now appears to regard it as a distinct order, under the name of Phytosauria.

Family Phytosauridæ.—This family is best known by the type genus *Phytosaurus* (*Belodon*); originally described from the Keuper,



Fig. 1082.—Right lateral view of the skull of *Phytosaurus cylindricodon*; from the Keuper of Würtemberg. Much reduced. The vacuities in the cranium are the preorbital, the orbit, and the infratemporal fossa. (After Meyer.)

or Upper Trias of Würtemberg, but subsequently found in beds of approximately equivalent age in both India and North America. In the skull (figs. 1082, 1083) the orbit is separated by a bony bar from the infratemporal fossa; there is a large preorbital vacuity,

[1] According to Dr Koken.

and the supratemporal fossa is exceedingly small. The nasals reached the premaxillæ and completely surrounded the nares—thus presenting a feature unknown in any other vertebrate; while the orbits were somewhat irregular in contour, and directed in part laterally, and in part frontally. The teeth are sharp and pointed,

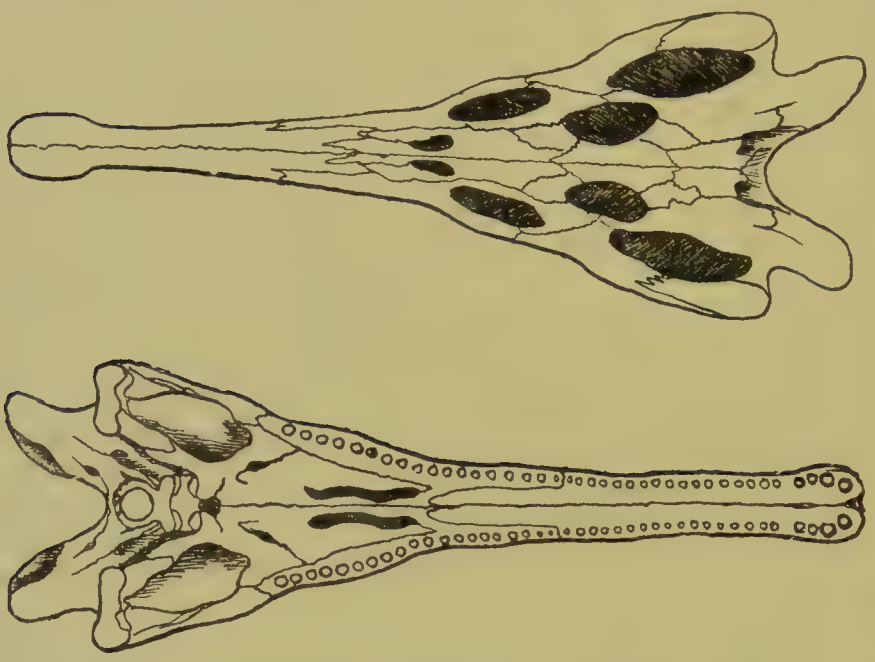


Fig. 1083.—Frontal and palatal aspects of the cranium of *Phytosaurus cylindricodon*. The anterior vacuities in the upper figure are the anterior nares, and the slits in the lower figure are the posterior nares. (After Meyer.)

with serrated antero-posterior ridges (carinæ); and in the anterior part of the jaw (fig. 1084) are subcircular in transverse section, but posteriorly are laterally compressed. There was no ventral armour. In the apparently nearly allied *Stagonolepis*, of the Upper Trias (Keuper) of Elginshire, there was, however, a well-developed ventral dermal armour; the teeth were blunt and swollen; and the pattern of the sculpture on the dorsal scutes was different. This genus was originally founded upon the evidence of these scutes, which were thought to have belonged to a Ganoid Fish. The name *Episcoposaurus* has been applied to a North American Triassic form which is regarded by Professor Cope as allied to *Phytosaurus*.

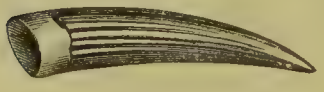


Fig. 1084.—Tooth of *Phytosaurus carolinensis*; from the Trias of South Carolina. Reduced.

Family Parasuchidæ.—The single genus *Parasuchus* occurs in the same lower Mesozoic horizon (Maleri beds) in India which

yields the remains of *Phytosaurus*, and is very imperfectly known. It differs from the preceding family by the structure of the ventral part of the basioccipital, which approximates to the Rhynchocephalian type.

Suborder 3. Eusuchia.—This suborder is taken to comprise all the post-Triassic Crocodilia. These were, indeed, originally divided into two suborders, but subsequent researches have shown that they are so closely connected as to render such division inadvisable. In all these forms the premaxillæ, maxillæ, and palatines develop inferior palatal plates meeting in the middle line beneath the narial passage, and thus completely separating the latter from the mouth, and causing the formation of secondary posterior nares, which in some instances are situated immediately behind the palatines, but in others (as in the figure of *Crocodilus* given on page 1192), owing to the development of similar plates by the pterygoids, behind the latter bones. The object of this peculiar arrangement is to enable these animals to drown their prey by holding it in their open mouths under water, which is thus entirely prevented from entering the air passages. A gradual evolution of this structural feature can be traced from the last suborder, where it is entirely wanting, to the generalised, and thence to the most specialised, members of this division. Other characteristic features are found in the terminally-situated, and usually undivided, nares; in the non-appearance of the vomers on the palate; in the bony middle eustachian canal; and the presence of not more than four or five teeth in the premaxillæ. There is no clavicle; the coracoid is much elongated; the pubis is entirely excluded from the acetabulum (fig. 1081); and there are five digits in the manus and four in the pes (fig. 1079). This suborder may be divided into two series according to the development or non-development of palatal plates by the pterygoids, and the form of the vertebræ.

The occurrence in all the groups of the Eusuchia of long-jawed and short-jawed forms is so suggestive of the direct origin of the existing Gharials from long-jawed Mesozoic types, and of the Crocodiles and Alligators from short-jawed forms of the same epoch, that Dr Koken adopts this view, and divides the families according to this grouping. There is, however, considerable difficulty in accepting this view, since it would appear unlikely that all the modern Crocodilians would have attained such a similarity in cranial and vertebral characters if they had totally different origins.

A. Amphicœlian Series.—In this the more generalised series the centra of the vertebræ are usually amphicœlous; the pterygoids do not develop palatal plates; and the dorsal scutes are usually arranged in only two longitudinal rows, and are keel-less. The ventral buckler is generally divided into an anterior and a posterior

portion, but may be single; while in the transverse rows of this buckler the scutes always imbricate anteriorly, but in the posterior part usually articulate by suture; each scute being invariably composed of a single piece of bone.

It may be incidentally mentioned here that while in the anterior region of the ventral buckler of all Crocodiles the component scutes of each transverse row articulate together by suture with those on either side, yet, as will be gathered from the foregoing characters, in the posterior portion of the same buckler in the present series the articulation of the different transverse rows with one another may be either by suture, or by imbricating like the tiles on a roof.

The present series ranges in time from the Lias to the Lower and Middle Cretaceous, and is especially characteristic of the European strata.

Family Teleosauridæ.—The members of this family are readily distinguished from the more specialised forms by the circumstance that the supratemporal fossæ are always much superior in size to the orbits, and that the latter are completely separated by a bony bar from the infratemporal fossæ; both these features being well shown in the accompanying figure of the cranium of *Steneosaurus*. In front of the orbit there is always a well-marked vacuity (not

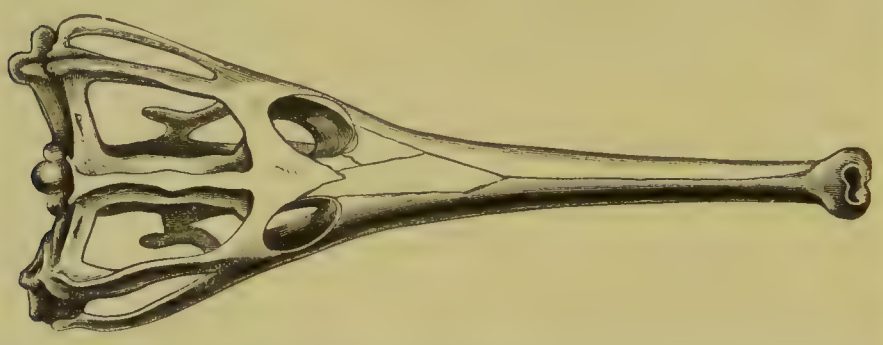


Fig. 1085.—Upper view of the cranium of *Steneosaurus Heberti;* from the Oxford Clay of France. Much reduced. The bones on the right side of the rostrum are imperfect, and there should have been a line connecting the apex of the frontals with the suture dividing the maxillæ. The large vacuities behind the orbits are the supratemporal fossæ, below which are the infratemporal fossæ.

shown in the figure); the dorsal scutes, when present, are rounded, and arranged in two longitudinal rows; while the ventral buckler is divided, and the component scutes of the posterior transverse rows are united by suture. The axis vertebra carries two facets for its rib, as in Dinosaurs. The members of this family were of marine habits, and range throughout the Lias and Jurassic system of Europe. They may be divided into two subfamilies.

In the subfamily *Teleosaurinæ* the skull is generally produced into a long slender rostrum, like that of the existing Gharial; the nasals

are separated by a long interval from the premaxillæ; the orbits are of regular contour, and directed more or less completely frontally; while the nares look more or less anteriorly. The dermal armour is fully developed, and sclerotic plates were not present in the eye. The type genus *Teleosaurus* comprises small or medium-sized species, and is readily characterised by the teeth being inclined horizontally outwards, and extremely numerous. It is confined to the Lower Jurassic, and is abundant in the Stonesfield slate of Oxfordshire, and the nearly equivalent beds of Caen, in Normandy. The most abundant genus is, however, *Steneosaurus* (fig. 1085), in which *Mystriosaurus* may be included, characterised by the elongated snout, the nearly vertical direction of the teeth, and the large size of the supratemporal fossæ, which in some species attain enormous dimensions. In the Liassic forms, separated generically by some writers as *Mystriosaurus*, the orbits are somewhat oblique, and the supratemporal fossæ are never excessively large; but in the numerous species of the Lower and Middle (Oxford Clay) Jurassic the direction of the orbits is entirely frontal, and the supratemporal fossæ are very large. In the figured *S. Heberti*, of the Lower part of the Oxford Clay, the skull is somewhat intermediate in these respects; the orbits being slightly oblique, and the supratemporal fossæ large. This genus does not appear to have survived above the Kimeridge Clay. In *Pelagosaurus* (fig. 1086) we have an



Fig. 1086.—Right lateral view of the skull of *Pelagosaurus typus*; from the Upper Lias of Normandy. Reduced. *T*, Supratemporal fossa; *O*, Orbit.

allied genus, represented only by two species of Liassic age; it is distinguished from the preceding by several characters; but more especially the form of the posterior nares, and the smaller and rounded supratemporal fossæ. The remains of the small *P. typus* are especially abundant in the Upper white Lias of Normandy, and the marvellously perfect preservation of some of the skeletons has enabled the bony anatomy of this species to be as completely studied as in the case of an existing form. In *Machimosaurus*, of the Kimeridge Clay (Upper Jurassic) of both England and the Continent, and *Teleidosaurus*, of the Fullers' Earth (Lower Jurassic) of Normandy, we have two genera in which the skull becomes much shorter and broader, the teeth stouter and less numerous, and the orbits more oblique; and which thus connect the present with the

next subfamily. *Machimosaurus*, which occurs both in France and England, is the largest member of the order, the length of the mandible exceeding 50 inches; the skull has been referred to *Pliosaurus*. The teeth closely resemble those of *Goniopholis*, having conical and deeply fluted crowns.

With the second subfamily, or *Metriorhynchinæ*, we come to a very remarkable group of Crocodiles, presenting certain specialised features unknown elsewhere in the entire order. The skull (fig. 1087) is either of moderate length or comparatively short; the nasals are either in contact with the premaxillæ, or separated therefrom by a short interval; the nares are directed frontally; the orbits are of very irregular contour, and placed completely on the sides of the skull; and the teeth, which are never very numerous, are always of considerable size, and directed more or less nearly

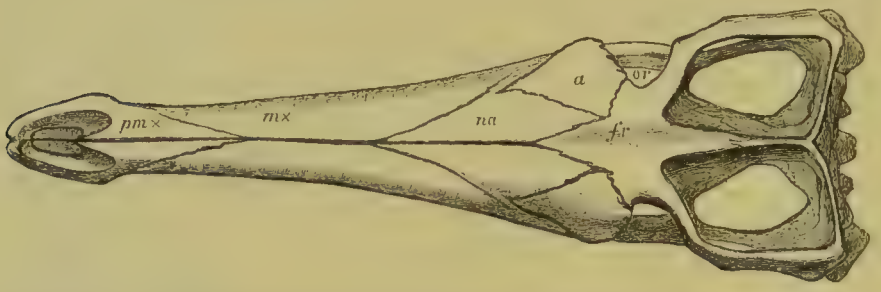


Fig. 1087.—The cranium of *Metriorhynchus hastifer*; from the Kimeridge Clay of Normandy. One-sixth natural size. *pmx*, Premaxilla; *mx*, Maxilla; *na*, Nasal; *a*, Prefrontal; *fr*, Frontal; *or*, Orbit. (After Deslongchamps.)

vertically, while there is no vacuity in the mandible. The most remarkable features of the group are, however, the development of a ring of bony plates in the sclerotic of the eye, and the general or universal absence of a dermal armour. It is, indeed, very curious to notice the correlation of these two features, since there is no known instance of the presence of both sclerotic plates and of dermal scutes in any reptile. The pelvis of this subfamily is also worthy of notice. Thus the ilia are very small subtriangular bones articulating with long and downwardly curved sacral ribs; while the ischia are enormously large, with the shape of an isosceles triangle. This presents a remarkable contrast to *Steneosaurus*, where the sacral ribs are straight and directed outwards, while the ilium is larger, with a considerable portion projecting above the costal articulation. In the genus *Metriorhynchus* the skull (fig. 1087) is of moderate length, and frequently somewhat slender, with the frontal region slightly sculptured; there is a more or less well-marked premaxillary expansion; the prefrontals (*a*) are very large, and overhang the orbits; while the teeth are curved and carinated, with the

enamel generally fluted at the base of the crown, but without serrations on the carinæ. The pectoral limbs are extremely small. This genus ranges from the Oxford Clay to the Portland Oolite.

In the Oxford Clay and Kelloway rock, both of the Continent and England, we meet with *M. superciliosus* and *M. moreli*, which are readily distinguished by the sculpturing of the frontals and the form and relations of the prefrontals. Beautiful examples of this genus occur in the Oxford Clay near Peterborough, which exhibit the absence of dermal scutes; a skull from this locality, to which the name *Steneosaurus dasycephalus* has been applied, may be referred to *M. superciliosus*. The Portlandian form was described as *Steneosaurus gracilis*. It is probable that *Gnathosaurus* and *Rhacheosaurus* are synonyms. The most specialised genus is *Geosaurus* (*Cricosaurus* or *Dacosaurus*), in which the skull is comparatively short, and is devoid of frontal sculpture, and also of the premaxillary expansion; while the teeth (fig. 1088) are compressed, smooth, and carinated, with distinct serrations on the carinæ. The type species, which occurs in the Lower Kimeridgian of Bavaria,



Fig. 1088.—Crown of tooth of *Geosaurus maximus*; from the Kimeridge Clay of Ely. (After Wood-Mason.)

and is of comparatively small size, was long thought to belong to the *Mosasauridæ*. A much larger form, occurring in the Kimeridge, and perhaps the Oxford, Clay of England and the corresponding beds of the Continent, has been described under the name of *Dacosaurus*, but can be only specifically distinguished from the type. A tooth is shown in the accompanying woodcut. It is not improbable that vertebræ from the Lower Greensand of Germany, described under the name of *Enaliosuchus*, indicate a closely allied form.

As members of this family, of which the serial position is uncertain, may be mentioned small forms respectively from the Kimeridgian of Bavaria and France, to which the names *Æolodon* and *Crocodilæmus* have been applied, both of which have a dermal armour; the ventral shield consisting of a number of small and closely-joined scutes. In the type of *Æolodon* these scutes are only slightly pitted, and the teeth alternate in size.

Family Goniopholididæ.—The members of this family resemble

existing Crocodiles in having an open channel connecting the infra-temporal fossa with the orbit. The orbits themselves are, moreover, usually but slightly smaller than the supratemporal fossæ, or only exceed them but little in size; while there is no preorbital vacuity. The dorsal scutes are rectangular, and may be arranged either in two or in several longitudinal rows; while the ventral armour may form either a single or a double buckler, in which the posterior transverse rows of scutes may either imbricate or articulate by suture. The members of this family inhabited freshwaters, and they range in time from the Purbeck (Upper Jurassic) to the Wealden (Lower Cretaceous), and not improbably also to the Upper Greensand. Nearly all the known forms are European, but one genus which may belong to this family is American; and the family is probably also represented in the Cretaceous of India. Three subfamily divisions have been proposed, but before discussing these we may allude to the genera *Suchosaurus* of the English Wealden, and *Hyposaurus* of the Cretaceous of North America and Brazil, which not improbably belong to this family, although their precise affinities are not yet satisfactorily determined. The type of the former genus is of very large size, and has the teeth greatly compressed; while in the latter the posterior teeth are of this type, but the anterior ones are rounded like those of *Goniopholis*, and the symphysis of the mandible is elongated.

The first subfamily, or *Petrosuchinæ*, is very imperfectly known, and is represented only by the genus *Petrosuchus*, of the English Purbeck beds, in which the posterior nares are placed near the middle of the skull, as in many of the *Teleosauridæ*, and the orbits are considerably smaller than the supratemporal fossæ. The cranium itself is of moderate length.

The members of the second subfamily, or *Goniopholidinæ*, have the posterior nares placed more posteriorly than in the preceding group; while there are two longitudinal rows of dorsal scutes; and the ventral buckler is divided, with the transverse rows of scutes in the posterior portion articulating by suture. In the first, or Longirostrine, section of this subfamily the skull is elongated like that of the existing Gharial; the nasals do not reach the nares, the splenial bone enters into the mandibular symphysis, and the teeth are numerous, and all nearly similar in size. It is represented only by *Pholidosaurus* (*Macrorhynchus*) of the German and English Wealden. In the Brevirostrine section, on the other hand, the skull is short, like that of the true Crocodiles, the nasals sometimes reach the nares, the splenial enters but very slightly into the symphysis of the mandible, and some of the teeth are much larger than the others. The dorsal scutes present the peculiarity of articulating with one another by means of a peg at one angle which fits into a

socket in the adjacent scute; an arrangement very similar to that obtaining in the scales of certain Ganoid fishes. The genus *Goniopholis* is very characteristic of the Wealden and Purbeck, and has a cranium of moderate length, with the nasals not reaching the nares, and the orbits rather smaller than the supratemporal fossæ. The type species attained very large dimensions, and was long since made known to the world by the late Dr Mantell, under the name of the Swanage Crocodile; its blunt and grooved teeth, and characteristic scutes, being comparatively common in the Wealden stone quarries of Sussex. This genus has been recently recorded from the Jurassic of North America, where it had been previously described as *Amphicotylus*. Allied but considerably smaller forms from the Dorsetshire Purbeck constitute the genera *Nannosuchus* and *Oweniasuchus* (*Brachydectes*). The most specialised genus, however, appears to be the minute *Theriosuchus* of the Purbeck, which, in having the orbits slightly larger than the supratemporal fossæ, approximates to the next subfamily, although retaining the pegged dorsal scutes of *Goniopholis*. The nasals in this genus reach and partly divide the nares, as in the true Crocodiles; and we thus have a comparatively close approximation to existing forms, which is rendered still more manifest by the members of the next group.

In the genus *Bernissartia*, of the Belgian Wealden, which forms the type of the subfamily *Bernissartiinæ*, the skull is comparatively short and broad, and has the posterior nares placed very close to the occipital condyle; while the orbits are decidedly larger than the supratemporal fossæ. Like existing Crocodiles, these reptiles were provided with more than two longitudinal rows of dorsal scutes (which have no peg-and-socket); while their ventral buckler is undivided, and has the transverse rows of scutes imbricating throughout. The resemblance to existing forms being completed by the pectoral limbs being considerably shorter than the pelvic pair. The vertebræ, however, still retained the primitive amphicœlous character. It seems probable, from the position of the posterior nares, that the imperfectly known genus *Hylæochampsa*, from the English Wealden, is a closely allied form of rather larger dimensions; and it is not unlikely that certain procœlous vertebræ from the same formation which have been described under the name of *Heterosuchus* may belong to this form; while others from the Cambridge Greensand and the Greensand of Austria, which have been referred to *Crocodilus*, may also indicate allied reptiles, although there is a possibility that the owners of these vertebræ belonged to the next series. It will thus be seen that if *Hylæochampsa*, or an allied form, had such procœlous vertebræ, it would only require the development of palatal plates to the pterygoids to convert it into a Crocodilian of the modern type; and it is highly probable that such a form once ex-

isted, since it is most unlikely that the change from amphicœlous to procœlous vertebræ took place precisely at the same time as the pterygoids developed palatal plates. On the other hand there is an equal *primâ facie* probability that these two changes may have occurred in the reverse order to that indicated above.

B. Procœlian Series.—In this series the vertebræ, with the exception of five, are procœlous; the pterygoids develop palatal plates to prolong the narial passage (fig. 1089); and all the eustachian canals are enclosed in bone. The dorsal scutes are, moreover, always arranged in more than two longitudinal rows; and when there is a ventral buckler it is undivided, and invariably consists of more than eight rows of imbricating scutes, in which each scute is composed of two separate pieces of bone. The axis vertebra differs from that of the *Teleosauridæ*, in having no costal articulations; its rib having been shifted forward on to the centrum of the atlas, or odontoid process.

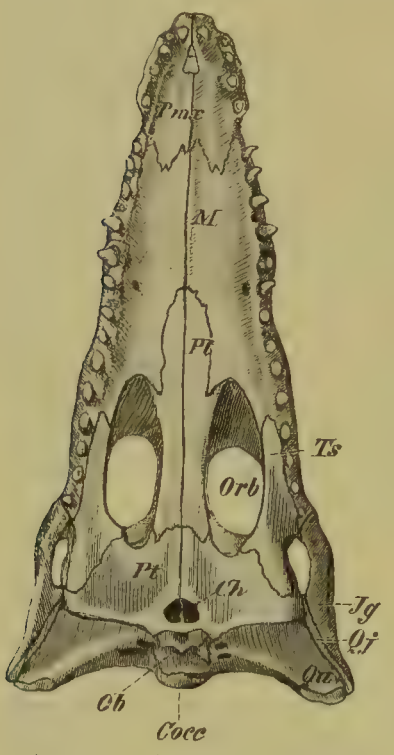


Fig. 1089.—Palatal aspect of the cranium of *Crocodilus*. Reduced. *Pmx*, Premaxilla; *M*, maxilla; *Pl*, Palatine; *Ts*, Transverse; *Pt*, Pterygoid; *Jg*, Jugal; *Qj*, Quadratojugal; *Qu*, Quadrate; *Ob*, Basioccipital; *Cocc*, Occipital condyle; *Orb*, Orbit; *Ch*, Posterior nares.

Family Crocodilidæ.—All the sufficiently known members of this series may be included in a single family, which agrees with the *Goniopholididæ* in the free communication of the infratemporal fossa with the orbit, which is considerably larger than the supratemporal fossæ. This family is first definitely known from the Upper Cretaceous, and continues to the present day, being represented in the freshwaters of most of the warmer regions of the globe. If, however, the procœlous vertebræ mentioned in the last series from the Greensand and Wealden really indicate members of the present family, it will date from the latter horizon. The form of the skull affords grounds for two sectional divisions.

The Longirostrine section is represented at the present day only by the true Gharial (*Garialis*) of the Ganges, and Schlegel's Gharial of Borneo. The skull is produced into a long narrow rostrum (fig. 1091), with the dental borders nearly straight; the nasals never extend to the anterior nares, and are frequently separated from the

premaxillæ; the supratemporal fossæ are of somewhat large size, and sometimes exceed the orbits in this respect; while the mandibular symphysis is very long, and embraces the anterior portion of the splenial bone. The teeth are always numerous, and are only slightly unequal in size; and neither of the existing species is provided with a ventral armour. In this group *Rhamphosuchus*, of the Pliocene of the Siwalik Hills of India, was a gigantic form probably between fifty and sixty feet in length, and characterised by the stoutness of the teeth, of which the upper series bites on the outer side of the lower, as in the Alligators, instead of interlocking with them as in other members of this group. In *Thoracosaurus*, again, of the Cretaceous of North America, we have a genus remarkable for retaining the preorbital vacuity of the *Teleosauridæ*, and in having the supratemporal fossa larger than the orbit; both these features apparently pointing to the direct descent of this genus from the last-named family, without having passed through the intermediate stage of the *Goniopholididæ*. The existing Indian *Garialis gangeticus*, of which the dental succession is shown in fig. 1090, is one of the existing species of Reptiles of which remains are found in the Pliocene of the Siwalik Hills. The same deposits have also yielded two more or less nearly allied extinct species; while in the somewhat older beds of Sind there occur two other species differing considerably in the form of the orbit and other cranial characters from the existing representative of the genus. One of these extinct species (*G. pachyrhynchus*) appears to have attained dimensions fully equal to those of *Rhamphosuchus*. Another Gharialoid provisionally referred to the present genus occurs in the Middle Eocene of Bracklesham, in Sussex; while species from the Cretaceous of North America, which have been described under the generic name of *Holops*, may prove to be allied either to the present or to the next genus. In *Tomistoma*, typically represented by the existing *T. Schlegeli* of Borneo, may be included the fossil forms described under the names of *Melitosaurus* and *Garialosuchus* (fig. 1091). This genus is readily distinguished from *Garialis* by the circumstance that the nasals extend forwards to articulate with the premaxillæ (fig. 1091), instead of being separated from them by a long interval. A large fossil form (*Melitosaurus*) occurs in the Miocene of Malta, and a smaller (*Garialosuchus*) in that of Austria. Another Gharialoid,



Fig. 1090. — Teeth of *Garialis gangeticus*, showing succession of germs (*b*, *c*) beneath the tooth in use (*a*). (After Owen.)

from the Upper Cretaceous of France and Maastricht, originally described as *Garialis macrorhynchus*, has also been provisionally included in the same genus. This form is, however, referred by

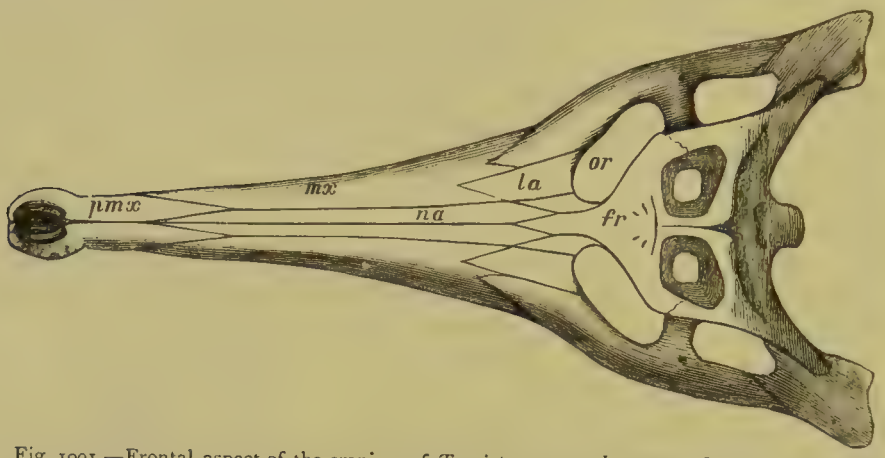


Fig. 1091.—Frontal aspect of the cranium of *Tomistoma eggenburgense*; from the Miocene of Austria. One-tenth natural size. *pmx*, Premaxilla; *mx*, Maxilla; *na*, Nasal; *la*, Lachrymal; *fr*, Frontal; *or*, Orbit. The vacuity behind the orbit is the infratemporal fossa. (After Toula and Kail.)

Dr Koken to *Thoracosaurus*, although it has no preorbital vacuity, and the nasals reach the premaxillæ. It appears to connect the typical *Thoracosaurus* with the existing *Tomistoma*. Finally, the

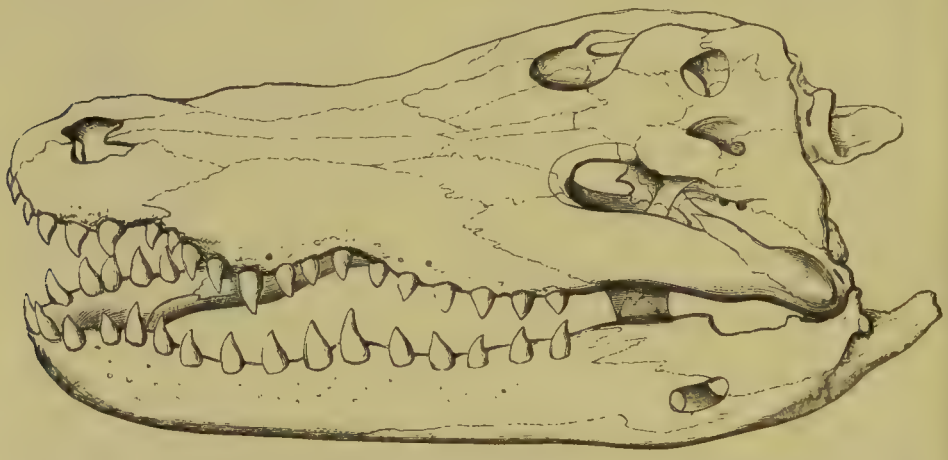


Fig. 1092.—Oblique left lateral and superior view of skull of *Crocodilus palustris*; India. Much reduced. The two small vacuities to the right are the supratemporal fossæ; those in advance are the orbits, while the single vacuity to the left is the nares; the bones in advance of the latter are the premaxillæ, and those behind the nasals.

imperfectly known *Thecachampsa*, from the Miocene of North America, should probably be placed in the present group.

The second, or Brevirostrine section, includes the true Crocodiles and Alligators, and is characterised by having the skull short, or

moderately elongated, with its dental borders thrown into distinct festoons (fig. 1092); by the nasals always reaching the premaxillæ, and frequently extending down to the anterior nares (as in fig. 1092); and also by the orbits being always larger than the supratemporal fossæ. The short symphysis of the mandible, from which the splenial element is entirely excluded (fig. 1093), is another striking feature. The teeth, moreover, vary in size in different parts of the jaws; and usually the third and ninth in the upper, and the fourth, and frequently also the first and eleventh, in the lower jaw (fig.

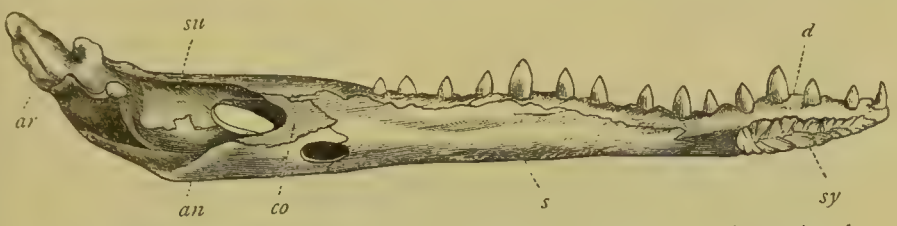


Fig. 1093.—Inner view of the left ramus of the mandible of a Crocodile. Reduced. *an*, Angular; *ar*, Articular; *co*, Coronoid; *d*, Dentary; *s*, splenial; *su*, Surangular; *sy*, Symphysis.

1093), are considerably larger than any of the rest. In the type genus *Crocodilus* the upper and lower teeth mutually interlock; the first lower tooth bites into a perforation or a pit in the cranium, and the fourth into a lateral notch; while the third lower tooth is small. There is, moreover, no ventral armour. This genus is now distributed over nearly all the warmer regions of the globe, and it appears to have had an equally extensive distribution in Tertiary times.

The earliest representative of this genus seems to be *C. Spenceri*, of the Lower Eocene of both England and Italy, which was a species with a comparatively long muzzle like that of the living American *C. intermedius*. The genus is also represented in the Middle Tertiaries of Europe and North America. In the Pleistocene of Queensland we meet with remains of the existing *C. porosus* (fig. 1079), which now ranges from Australia to Eastern India; while in the Pliocene of the Siwalik Hills of India there occur species closely allied to the short-snouted *C. palustris* (fig. 1092) of that country, which makes the nearest approach in cranial characters to the Alligators and their allies.

Diplocynodon is an extinct genus found in the Tertiaries of both Europe and North America, which presents characters intermediate between *Crocodilus* and *Alligator*. Thus the cranium (fig. 1094) is very short and broad; the upper teeth bite on the outer side of the lower; the fourth lower tooth is normally received into a notch (but occasionally into a pit) in the cranium; the third lower tooth is as large as the fourth; and there is a complete ventral armour. In Europe this genus ranges from the Upper Eocene to the Lower Miocene (Upper Oligocene), and is common in the Tertiaries of the

south of England, and also in those of France and Germany; some of the species from the latter deposits having been described as *Alligator*. The genus has also been recorded from the Upper Eocene of North America. The last, and in respect of cranial characters the most specialised, group of Crocodiles is now divided[1] into the two genera *Caiman* and *Alligator*. In these forms both the first and the fourth lower tooth are received into pits in the upper jaw, so as to be concealed when the mouth is closed; the upper teeth bite on the outer side of the lower ones; the supratemporal fossæ are very small, and are occasionally obliterated; and the third lower tooth is smaller than the fourth. *Caiman* is distinguished by the presence of a ventral armour, and also by the circumstance that the nasals do not extend across the nares; and



Fig. 1094.—Oblique left lateral and palatal view of the facial part of the cranium of *Diplocynodon hantoniensis*; from the Upper Eocene of Hampshire. Reduced.

is now confined to Central and South America. In *Alligator*, on the other hand, which occurs at the present day in North America and China, the ventral armour is absent or extremely thin, and the nasals extend forwards so as to divide the narial aperture. Remains which are probably referable to *Caiman* occur in the Pleistocene cave-deposits of Brazil; but it does not appear that there is any certain evidence of fossil species of *Alligator*; the European, and probably some of the North American forms which have been referred to that genus, belonging to *Diplocynodon*. Finally, the name *Isselosaurus* has been recently applied to Crocodilian remains from the Middle Eocene of France which may really belong to one of the above-mentioned genera.

Order X. Ornithosauria.—The Pterodactyles, as the members of this extinct order are commonly termed, are among the most remarkable and strange Reptilian forms that Palæontology has

[1] According to the arrangement adopted by Mr Boulenger in his British Museum Catalogue of this order.

yet revealed to us. So strange, indeed, are they that some authorities have considered that the Ornithosaurs are entitled to rank as a distinct class; but they are essentially Reptiles, and agree in their intrinsic characters with the other two orders placed in the branch now under consideration. All their organisation is, however, modified for the purpose of flight through the air. Thus the body was supported during flight by a membranous expansion, or *patagium*, which was mainly borne by the greatly elongated phalangeals of the ulnar, or outermost digit of the manus (fig. 1095, marked iv); but which also extended along the sides of the body to embrace the hind limbs and tail (fig. 1098). The vertebræ are procœlous, and have their neuro-central suture obliterated; the precaudal series is not numerous; the cervicals are longer than the dorsals; and from three to six vertebræ are anchylosed together to form the sacrum. The cervical ribs in those cases where they have been observed are of the Crocodilian type. The skull (figs. 1096, 1097) is relatively large; and although more or less bird-like in general contour, yet maintains the reptilian type by the presence of the supratemporal fossæ, bounded by the junction of the postorbital with the squamosal bone. Bird-like resemblances are, however, shown by the circumstance that the bones of the skull anchylosed together at an early age; and that the two rami of the mandible were completely welded together at their symphysis. Moreover, as in Birds, the greater portion of the upper jaws is formed by the premaxillæ;

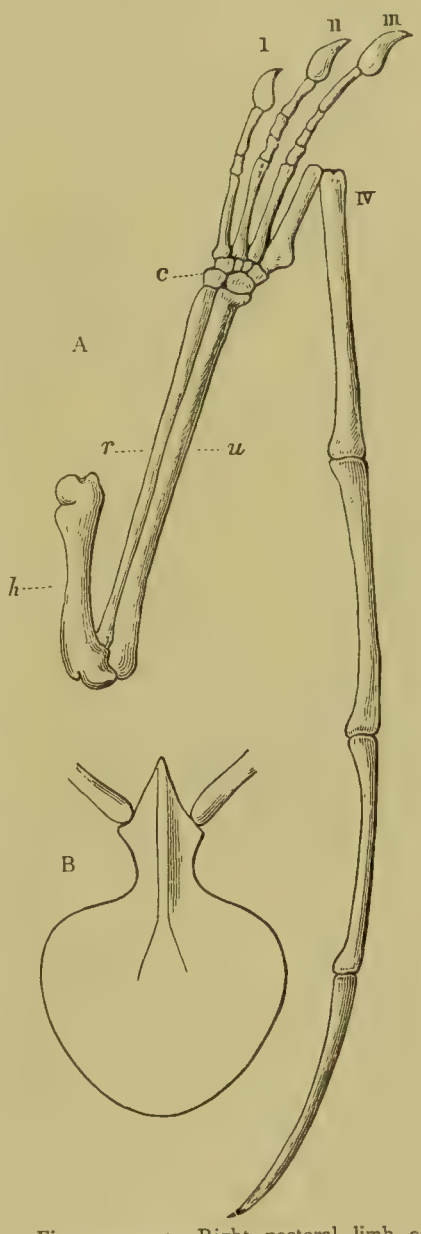


Fig. 1095. — A, Right pectoral limb of *Scaphognathus crassirostris*; B, Sternum and coracoids of *Pterodactylus*. *h*, Humerus; *r*, Radius; *u*, Ulna; *c*, Carpus; i–iv, Digits. These should have been numbered ii–v.

the nares are similarly approximated to the orbits, with the intervention of a preorbital vacuity, which (fig. 1096) may be very large; while the occipital condyle is situated on the base of the cranium; and the orbits are large, and there is generally an ossified ring in the sclerotic. The teeth are invariably simple and pointed; and are always implanted in separate sockets. In the pectoral girdle the scapula and coracoid are long and bird-like, and the latter has no fontanelle; there were no clavicles; but there was a broad heart-shaped sternum (fig. 1095, B), carrying a median keel superiorly. The angle of junction of the scapula and coracoid, as well as the keeled sternum, curiously resemble the corresponding parts in the skeleton of the Carinate Birds, and are consequently totally unlike those of the Ratitæ. The carpus consists of two main bones, one distal and the other proximal;[1] while on its radial side there is a small styliform ossification, regarded by Professors Owen and Marsh as the representative of the pollex—an identification which, if correct, will make the four remaining digits which are usually present the 2d, 3d, 4th, and 5th of the typical series, and not the 1st, 2d, 3d, and 4th as they are regarded by some writers (fig. 1095). The phalangeals of the ulnar digit, as already mentioned, are enormously elongated, and the terminal joint has no claw. The pelvis is relatively weak; and although the ilium is extended on both sides of the acetabulum, the structure of both this region and of the pelvic limbs is far removed from the avian type. Thus the pubis (or prepubis) is directed forwards, and the ischium is short and wide; while the pelvic limbs are relatively short. The fibula is, however, always fused with the tibia; and the astragalus may also unite with the latter bone; although the metatarsals always remain distinct both from one another, and also from the distal row of the tarsus. The greater number of the bones are hollow, and are frequently provided with pneumatic foramina, like those of Birds. The brain was bird-like, and the body was probably naked. In time this order ranges from the Lias to the Upper Chalk; and was especially abundant in the Upper Jurassic and Cretaceous strata of both the Old and New Worlds. Although the skeleton presents many remarkable resemblances to the Carinate Birds, yet these must be regarded as mainly due to adaptation for a similar mode of life; since it seems clear that the Pterodactyles are altogether off the direct line of the Avian pedigree.

Suborder 1. Pteranodontia. — In this suborder teeth are totally wanting, and the jaws were probably completely ensheathed in horn, like those of Birds. The skull (fig. 1096) has an enormous supraoccipital crest, projecting far behind the occiput; and the nares

[1] The carpus is erroneous in fig. 1095.

were completely confluent with the preorbital vacuities. According to Professor Marsh, these reptiles were mostly of gigantic size; some having a spread of wing of nearly or quite 25 feet. And in order to aid the powerful patagium in flight, the pectoral girdle was generally strengthened by the anchylosis of several vertebræ, and by the robust scapulæ articulating to the spines of these anchylosed

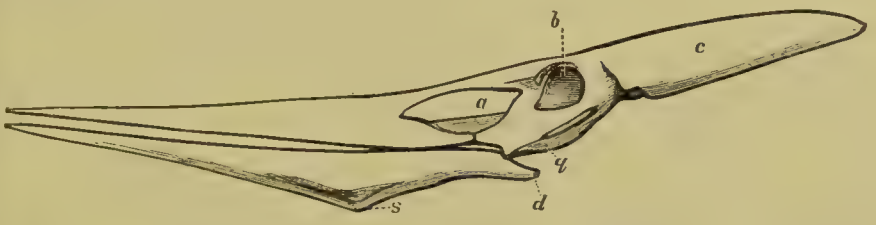


Fig. 1096.—Left lateral view of the skull of *Pteranodon longiceps*; from the Cretaceous of North America. One-twelfth natural size. *a*, Nares and preorbital vacuity; *b*, Orbit; *c*, Supraorbital crest; *d*, Angle of mandible; *q*, Quadrate; *s*, Symphysis (After Marsh.)

vertebræ; this peculiar feature being virtually a repetition of the pelvic girdle and sacrum on a much larger scale.

Family Pteranodontidæ.—The type genus *Pteranodon* (fig. 1096) occurs in the Cretaceous of North America; and although its members are generally of large size, it is also represented by one small species—*P. nanus*. The coracoid and scapula were united, but the oral aspects of the jaws have not the ridge and groove found in *Ornithochirus*. *Ornithostoma*, of the Cambridge Greensand, may have been an allied form. In *Nyctodactylus*, of the North American Cretaceous, Professor Marsh thinks that none of the dorsal vertebræ were anchylosed; and on this account the genus should perhaps form the type of a distinct family.

Suborder 2. Pterosauria.—In this, the typical, suborder teeth are present in both jaws; the cranium (fig. 1097) has no long supra-occipital crest directed backwards, and generally has the nares more or less completely separated from the preorbital vacuities. The scapula is (at least usually) not anchylosed to the neural spines of the dorsal vertebræ, which are distinct from one another. This suborder is mainly European.

Family Pterodactylidæ.—In the typical family the tail is short (fig. 1097); the jaws are toothed to their extremities; and the length of the metacarpus considerably exceeds half that of the ulna (fig. 1097). The skull, which is extremely bird-like, may be either long or short, and has the nares imperfectly separated from the preorbital vacuities; while in the pelvic limb the astragalus is always distinct from the tibia. In Europe this family is especially characteristic of the Upper Jurassic, and is abundantly represented in the Lower Kimeridgian lithographic limestones of Bavaria, which,

from their fine structure, have preserved not only the smallest bones, but not unfrequently also the impression of the membranous patagium. All the forms which can be certainly referred to this family are of small or moderate size. In *Ptenodraco*, of the lithographic limestones, we have a small Pterodactyle not larger than a sparrow, with a skull of very much the same contour as that of the latter, in

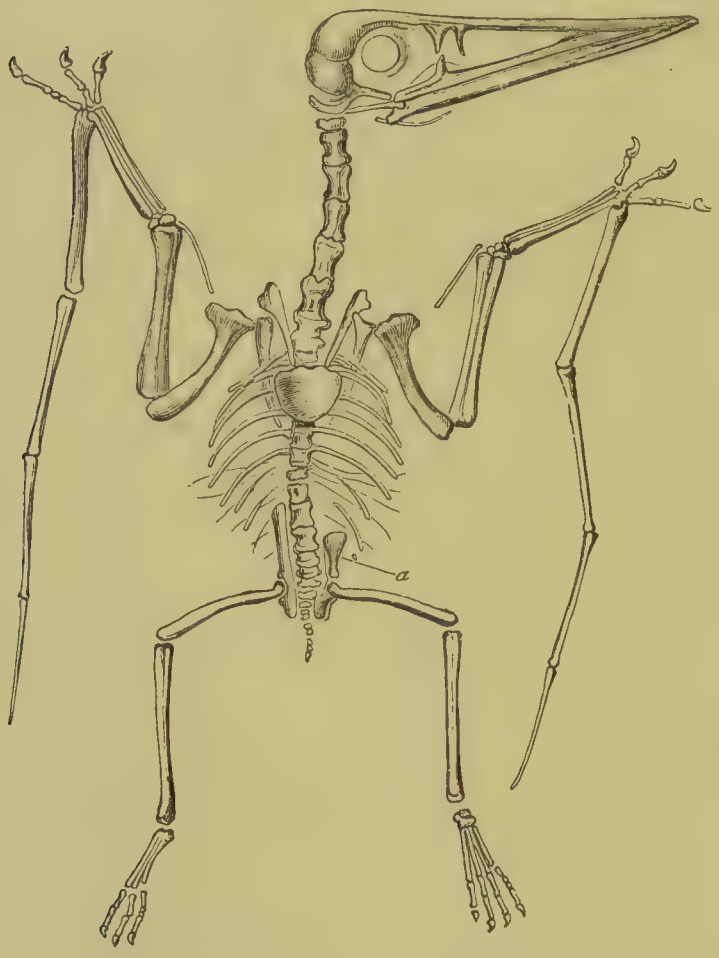


Fig. 1097.—Nearly entire skeleton of *Pterodactylus spectabilis;* from the Kimeridgian of Bavaria. The ventral aspect is shown; and on the right side the ilium, and on the left the pubis (*a*) is exposed.

which the teeth are confined to the extremities of the jaws, and the nares do not appear to be separated from the preorbital vacuities. *Pterodactylus* itself (of which *Ornithocephalus*[1] and *Diopecephalus*

[1] It has been proposed to take the name *Ornithocephalus* in place of *Ptenodraco*, a suggestion which is entirely opposed to all the rules of nomenclature. The first use of the former name in this sense was made by Fitzinger in 1826.

are synonyms), on the other hand, has the skull produced into a long beak or rostrum (fig. 1097), in which the teeth extend over a considerable space, and the large nares are slightly separated from the preorbital vacuities. The scapula is not anchylosed to the coracoid; and the pubes are short and rounded (fig. 1097). This genus appears to be confined to the lithographic limestones; the typical *P. antiquus* being about the dimensions of a woodcock.

Apparently allied to this genus is *Dermodactylus*, of the Jurassic of North America, in which the bones are said to have thicker walls. The type species is estimated to have had a spread of wing of from five to six feet. Finally, in *Cycnorhamphus*, of the Solenhofen limestones, we have a genus with a broad expanded beak, like that of a Swan, with the teeth confined to the anterior extremity. This genus is represented by a single species of comparatively large size, known as *C. suevicus*.

Here we may conveniently notice some gigantic Pterodactyles from the Cretaceous system of Europe, of which, owing to the exceedingly imperfect remains hitherto discovered, the family position must be left undetermined. Remains of some of those forms were originally regarded as belonging to Birds, and described under the names of *Palæornis* (Wealden) and *Cimoliornis* (Chalk). All these forms may be provisionally included under the generic name of *Ornithochirus*, although it is highly probable that some of them may really be distinct; and there does not at present appear any very good reasons for separating a Purbeck form for which the name *Doratorhynchus* has been proposed. Many of these Pterodactyles were of gigantic size; the spread of wing of some of the larger species being estimated at as much as 25 feet. Probably the tail was long; the jaws were toothed to their extremities, and frequently the upper anterior teeth curved forwards to project in advance of the muzzle. The oral surfaces of the upper and lower jaws were marked by a longitudinal ridge and groove; the skull was either short and stout, or much elongated; the scapula was often anchylosed to the coracoid; and in some instances the astragalus united with the tibia. It has also been suggested that *Ornithochirus* had but three digits in the manus, but this statement requires confirmation. The name *Cretornis* has been applied to the remains of *Ornithochirus* from the Chalk of Bohemia.

Family Rhamphorhynchidæ.—In this family the tail was at least usually long (as in fig. 1098); the extremities of the jaws were in many instances edentulous; and the length of the metacarpus was much less than half that of the ulna (fig. 1095). The skull (fig. 1099) was less bird-like than in the type family, with the nares separated by a distinct bar from the preorbital vacuity, and was

often comparatively short and stout; while in some instances the astragalus united with the tibia. This family certainly ranged from the Lias to the Upper Jurassic, but if *Ornithochirus* belong to it, its range must be extended to include the Cretaceous. In the genus *Scaphognathus* (fig. 1099) the teeth extend to the extremities of the jaws of the massive skull, in which the nares are separated by a broad bar from the larger preorbital vacuities. The tail of the type species is unknown, and in Goldfuss' restoration (fig. 1099) it was made like that of *Pterodactylus;* but Professor Zittel considers that it was elongated like that of *Rhamphorhynchus* and *Dimorphodon* (fig. 1101). The type species, which attains considerable dimensions, occurs in the Kimeridgian limestones of

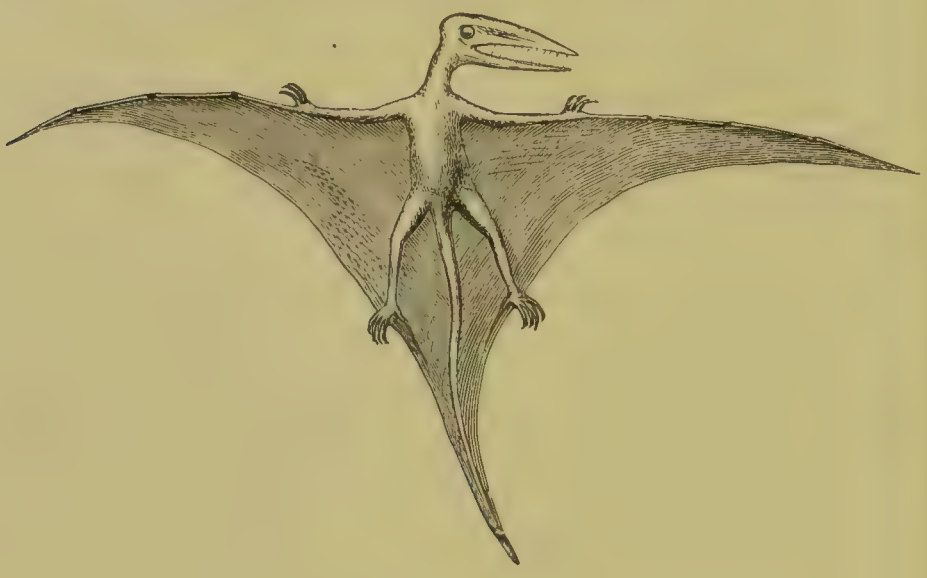


Fig. 1098.—Restoration of *Dimorphodon macronyx*. Reduced. (After Owen.)

Bavaria, but the genus is also represented in the Upper Lias of Whitby. It is noteworthy that the peculiar form and relations of the jugal and quadratojugal found in the Dinosaurian genus *Diplodocus* (fig. 1076) also obtain in *Scaphognathus*. In *Rhamphorhynchus*, of the Kimeridgian of Bavaria, the extremities of the jaws are usually devoid of teeth; while in the hinder region the teeth incline forwards instead of having the nearly vertical direction of those of *Scaphognathus*. The scapula and coracoid were sometimes anchylosed; the astragalus was generally distinct from the tibia; the pes had either four or five digits; the pubes were slender, bent, and joined by a bony symphysis; while the long tail was strengthened by the ossification of its tendons. The membranous patagium developed a leaf-like expansion at the extremity of the tail,

as is beautifully shown in a specimen of the typical *R. Muensteri*, of which a restoration is shown in the accompanying woodcut.



Fig. 1099.—The skeleton and patagium of *Scaphognathus crassirostris* according to the restoration of Goldfuss; from the Kimeridgian of Bavaria. Reduced. The presence of the first digit in the manus is incorrect; the tail should be long; while the patagium should have been more extended posteriorly, as in fig. 1098.

This species was of comparatively small size; but *R. grandis*, in which the astragalus united with the tibia, attained considerably larger dimensions. *Rhamphocephalus*, of the Lower Jurassic Stones-



Fig. 1100.—Restoration of *Rhamphorhynchus Muensteri* (*phyllurus*); from the Lower Kimeridgian of Bavaria. One-seventh natural size. (After Marsh.)

field slate, is distinguished from the preceding genus by the form of the teeth, and the great interorbital constriction of the cranium. *Dorygnathus*, from the Upper Lias of Germany, appears to

have been an allied genus. In the Lower Liassic genus *Dimorphodon* (fig. 1101) the jaws are toothed to their anterior extremities, and the hinder teeth of the mandible are much smaller than those in front. Both the nares and preorbital vacuities are of enormous size, and are separated by a narrow bar. The coracoid is anchylosed to the scapula; and the astragalus united to the tibia. *Dimorphodon* is thus the earliest known representative of the order; and the one species attained considerable dimensions. Its remains occur in the Liassic shales of Lyme Regis in Dorsetshire, and were first brought to notice in 1822 by the indefatigable Dean Buckland.

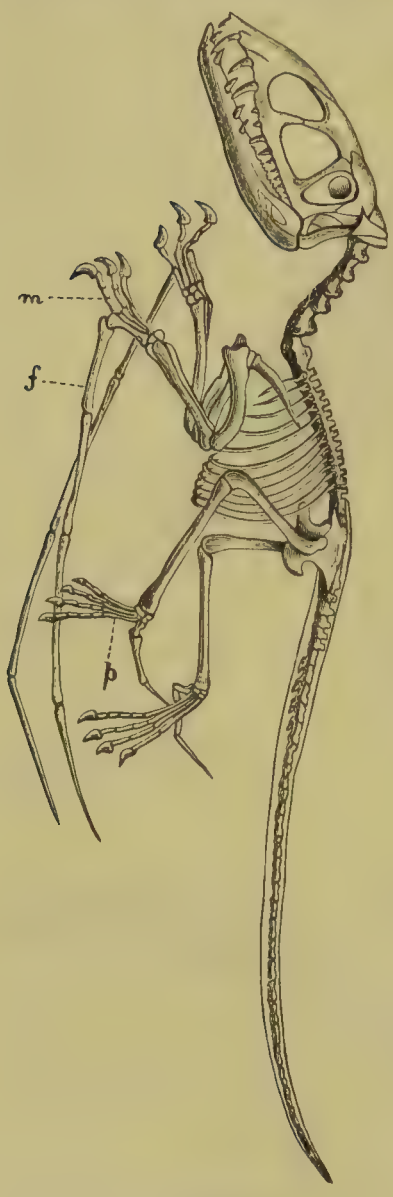


Fig. 1101. — Restored skeleton of *Dimorphodon macronyx*; from the Lower Lias. Reduced. *f*, Ulnar digit; *m*, Other digits; *p*, Metatarsus. (After Owen.)

Ordinal Position Uncertain.— Here may be noticed a genus of which the serial position must for the present remain undecided. It is known as *Ornithodesmus*, and was founded upon an imperfect sacrum from the English Wealden, which has been regarded as Avian, although its right to distinction from the Ornithosauria appears by no means certain. It may be observed that the so-called *Ornithopterus*, of the Upper Jurassic limestones of Bavaria, said to be characterised by the presence of only two digits in the ulnar digit of the manus, and which has been regarded as Avian, appears to have been founded upon an imperfect specimen of *Rhamphorhynchus*; and it may also be mentioned that the name *Ornithopterus* is preoccupied by the Lepidopterous genus *Ornithoptera*. Finally, it has been suggested that a tooth from the Trias of Italy described under the name of *Tribelesodon* may indicate an Ornithosaurian at that early period, but the evidence in support of that view is at present wholly insufficient.

LITERATURE OF REPTILIA.

1. BAUR (G.)—"On the Phylogenetic Arrangement of the Sauropsida." 'Journal of Morphology,' vol. i. (1887).
2. BOULENGER (G. A.)—"Catalogue of Chelonians, &c., in the British Museum" (1889).
3. BUCKLAND (W.)—"Geology and Mineralogy" (1837).
4. COPE (E. D.)—"Extinct Batrachia, Reptilia, and Aves of North America." 'Trans. Amer. Phil. Soc.,' vol. xiv. p. 100 (1871).
5. —— "Homologies of the Cranial Bones of the Reptilia, and the Systematic Arrangement of the Class." 'Proc. Amer. Assoc.' for 1870.
6. —— "The Relations between the Theromorphous Reptiles and the Monotreme Mammalia." 'Proc. Amer. Assoc.' for 1884.
7. —— "The Vertebrata of the Cretaceous Formations of the West." 'Rep. U.S. Geol. Surv. Terrs.,' vol. ii. (1875).
 See also numerous memoirs in various American serials.
8. CREDNER (H.)—"Die Stegocephalen und Saurier aus dem Rothliegenden des Plauen'schen Grundes bei Dresden." 'Zeitschr. deutsch. geol. Gesellschaft.' 1881-88.
9. DESLONGCHAMPS (E.)—"Notes Paléontologiques" (1863-69).
10. DOLLO (L.)—"Note sur les Dinosauriens de Bernissart," 5 parts. 'Bull. Mus. R. d'Hist. Nat. Belg.' 1882-84.
 —— "Note sur l'Osteologie des Mosasauridæ." *Ibid.* 1882.
 See also other memoirs in same and other serials.
11. GÜNTHER (A.) and MIVART (St G.)—"Reptilia." 'Encyclopædia Britannica,' 9th ed.
12. HULKE (J. W.)—"Presidential Addresses to the Geological Society." 1883-84.
13. —— "Supplemental Note on *Polacanthus Foxii*." 'Phil. Trans.' 1887, pp. 167-172, pl. viii.
14. —— "Contributions to the Skeletal Anatomy of the Mesosuchia, based on fossil remains from the clays near Peterborough, in the collection of A. N. Leeds, Esq." 'Proc. Zool. Soc.' 1888.
 See also other memoirs in 'Phil. Trans.' and 'Quart. Journ. Geol. Soc.'
15. HUXLEY (T. H.)—"A Manual of the Anatomy of Vertebrated Animals," 2d ed. London. 1871.
16. —— "On the Affinities between Dinosaurian Reptiles and Birds." 'Quart. Journ. Geol. Soc.,' vol. xxvi. (1870).
17. —— "On the Classification of the Dinosauria," *tom. cit.*
18. —— "On *Stagonolepis* and the Evolution of the Crocodilia," *ibid.*, vol. xxxi. (1875).
19. —— "On *Hyperodapedon*." *Ibid.*, vol. xliii. (1887).
 See also numerous memoirs in the same and other serials.
20. KIPRIJANOFF (W.)—"Studien über die Fossilen Reptilien Russlands." 'Mém. Ac. Imp. St Pétersburg,' vols. xxviii.-xxxi. (1881-83).
21. KOKEN (E.)—"Die Dinosaurier, Crocodiliden, und Sauropterygier des Norddeutschen Wealden." 'Pal. Abhandl.,' vol. iii., pt. 5 (1887).
22. LEIDY (J.)—"Cretaceous Reptiles of the United States." 'Smiths. Contrib. Knowl.,' vol. xiv. (1864).

23. LEIDY (J.)—"Contributions to the Extinct Vertebrate Fauna of the Western Territories." 'Rep. U.S. Geol. Surv. Terrs.,' vol. i. (1873).
24. LYDEKKER (R.)—"Catalogue of Fossil Reptilia and Amphibia in the British Museum." Parts i., ii., iii. (1888-89).
25. —— "Indian Pretertiary Vertebrata." 'Palæontologia Indica,' ser. 4, vol. i., pts. 3-5 (1879-85).
26. —— "Indian Tertiary and Post-Tertiary Vertebrata." *Ibid.*, ser. 10, vol. iii., pts. 6, 7 (1885-86).
27. —— "On Eocene and Mesozoic Chelonia and a tooth of (?) *Ornithopsis*." 'Quart. Journ. Geol. Soc.,' vol. xlv. (1889).
28. MARSH (O. C.)—"Classification of the Dinosauria." 'American Journal of Science,' ser. 3, vol. xxiii. (1882), and 'Rep. Brit. Assoc.' for 1884.
29. —— "Principal Characters of American Jurassic Dinosaurs." 8 parts. *Ibid.*, vols. xvi.-xxvii. (1878-84).
30. —— "Principal Characters of American Cretaceous Pterodactyles." *Ibid.*, vol. xxvii. (1884).
31. —— "Structure of the Skull and Limbs in Mosasauroid Reptiles." *Ibid.*, vol. iii. (1872).
32. MEYER (H. VON).—"Saurier des Muschelkalkes." (1847-55.)
33. —— "Saurier aus dem Kupfer-Schiefer der Zechstein-formation." (1856.)
34. OWEN (R.)—"Descriptive Catalogue of the Fossil Reptilia and Fishes in the Museum of the Royal College of Surgeons of England." (1854.)
35. —— "Catalogue of the Fossil Reptiles of South Africa in the Collection of the British Museum." (1876.)
36. —— "Monograph on the Fossil Reptilia of the London Clay." Part i., Chelonia (Owen and Bell). 'Palæontographical Society.' (1849.) Part ii., Crocodilia and Ophidia. *Ibid.* (1850.)
37. —— "Monograph on the Fossil Reptilia of the Wealden and Purbeck Formations." *Ibid.* (1853-59, and Supplements extending to 1876.)
38. —— "Monograph on the British Fossil Reptilia of the Oolitic Formations." *Ibid.* (1861.)
39. —— "Monograph on the Fossil Reptiles of the Cretaceous Formation." *Ibid.* (1851-64.)
40. —— "Monograph of the Fossil Reptilia of the Liassic Formations." *Ibid.* (1865 and 1870.)
41. —— "Monograph of the British Fossil Reptilia of the Kimmeridge Clay." *Ibid.* (1869.)
42. —— "Monograph of the British Mesozoic Reptilia." *Ibid.* (1873, 1875, and 1877.)
43. —— "Odontography." (1840-45.)
44. —— "Report on Fossil Reptiles." 'Rep. Brit. Assoc.' for 1839 and 1841.
45. —— "On Dicynodon." 'Trans. Geol. Soc.,' ser. 2, vol. vii. (1845).
46. —— "History of British Fossil Reptiles." (1849-84.)
47. —— "On Parts of the Skeleton of *Meiolania platyceps*." 'Phil. Trans.' 1888.
48. PHILLIPS (J.)—"Geology of Oxford and the Valley of the Thames." *Oxford.* 1871.
49. RILEY (H.) and STUTCHBURY (S.)—"Description of Remains of Saurian Animals from the Magnesian Conglomerate of Bristol." 'Trans. Geol. Soc.,' ser. 2, vol. v. (1840).

50. SEELEY (H. G.)—"On the Dinosauria of the Cambridge Greensand." 'Quart. Journ. Geol. Soc.,' vol. xxxv. (1879).
51. —— "On the Reptile Fauna of the Gosau Formation." *Ibid.*, vol. xxxvii. (1881).
52. —— "On the Dinosaurs of the Maastricht Beds." *Ibid.*, vol. xxxix. (1883).
53. —— "On the Mode of Reproduction of certain species of *Ichthyosaurus*." 'Rep. Brit. Assoc.' for 1880.
54. —— "Researches on the Structure, Organisation, and Classification of the Fossil Reptilia." Part i., *Protorosaurus Speneri;* part ii., *Pareiasaurus bombidens*. 'Phil. Trans.' 1887-88.
55. —— "Index to the Fossil Remains of Aves, Ornithosauria, and Reptilia in the Woodwardian Museum." *Cambridge*. 1869.
56. —— "The Ornithosauria." *Cambridge*. 1870.
See also numerous other memoirs in the above and other serials.
57. SOLLAS (W. J.)—"On a new Species of *Plesiosaurus*, accompanied by a Supplement on the Distribution of the Genus." 'Quart. Journ. Geol. Soc.,' vol. xxxvii. (1881).
58. WOODWARD (A. S.)—"The History of Fossil Crocodiles." 'Proc. Geol. Assoc.,' vol. ix. (1886.)

CHAPTER LVI.

CLASS AVES.

General Structure.

The fifth class of the Vertebrata is that of Aves, or Birds, which, as we have already mentioned under the description of the class Reptilia, presents a number of characters in common with the latter. Birds, indeed, as Professor Huxley remarks, are animals so similar to Reptiles in all the most essential features of their organisation, that they may be said to be merely an extremely modified and aberrant Reptilian type. Their differentiation is, however, so great as to indicate without doubt their right to form a distinct class. It will be unnecessary to recapitulate the characters common to Birds and Reptiles—together constituting the province Sauropsida—and we may accordingly proceed to note the distinctive features of the former class. It may be well, however, to observe before proceeding further that, according to the arrangement proposed by Professor A. Newton, Birds are divided into three primary divisions or orders, respectively known as Saururæ, Ratitæ, and Carinatæ; the fossil representatives of which will be noticed in the next chapter.

In the first place, all Birds, so far as can be ascertained, were provided with the peculiar epidermal covering known as feathers, which are totally unknown among the Reptiles; while ossifications in the dermis are extremely rare, and never take the form of bony scutes. No Bird, again, has procœlous vertebræ; while in all existing forms the centra of the cervicals have cylindroidal, saddle-shaped, articular surfaces, although these are amphicœlous in certain Mesozoic forms. In no cases are there sacral ribs for attachment of the ilia in the proper sacral vertebræ. The sternum has no backwardly-produced median processes for the ribs; all of which are attached superiorly to its lateral borders. If an interclavicle ever exists, it is fused with the clavicles into a compound bone

termed the furcula (fig. 1106). No Bird has more than three digits in the manus; all of which may be furnished with claws. The three elements of the pelvis are nearly always anchylosed together in the adult (fig. 1102); the ilium being produced in advance of the acetabulum (of which the inner wall is unossified), and the ischium and pubis directed backwards, in a more or less parallel direction, and only very rarely meeting in a ventral symphysis. The proximal row of the tarsus is always united with the tibia to form a tibio-tarsus; while the distal row coalesces with the

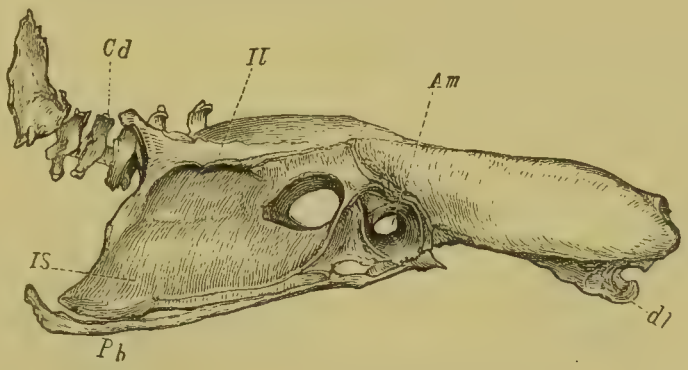


Fig. 1102.—Right lateral view of the pelvis and caudal vertebræ of a Fowl (*Gallus*). *Il*, Ilium; *Is*, Ischium; *Pb*, Pubis; *Am*, Acetabulum; *dl*, Dorso-lumbar vertebræ; *Cd*, Caudal do.

three median metatarsals to constitute a tarso-metatarsus. In all recent Birds only the right aortic arch is present; the arterial and venous circulations meeting only in the capillaries; and the blood is hot.

Some of the above characters are common to certain Reptiles; and it is only the whole of them collectively which can be regarded as characteristic of Birds as a class.

Noticing in rather more detail certain features of the osteology, it may be observed that the skeleton is usually remarkable for its combination of compactness and lightness, and also by the permeation of the greater number of the bones by air-cavities. The skull (fig. 1103) is formed on the general reptilian type, but is remarkable for the greater relative development of the brain-case, although this feature is nearly paralleled in the Ornithosauria. The component bones have a great tendency to unite in the adult by the obliteration of their sutures, and their texture is delicate and spongy, and totally unlike the ivory-like structure so generally observable among Reptiles. The single occipital condyle, which is mainly formed by the basioccipital, is not placed at the hinder extremity of the cranium, but becomes shifted forwards and downwards, so that the basal axis of the latter forms an angle with the axis of the

vertebral column. In Reptiles a similar feature occurs in the Ornithosauria. The inferior temporal arcade, formed by the jugal and quadratojugal (fig. 1103), and connecting the maxilla with the quadrate, is invariably present, but the superior temporal arcade is always wanting; and there are never distinct postorbitals or postfrontals. The complete inclusion of the parietals in the roof of the brain-case prevents the formation of the posttemporal fossæ, which constitute such a characteristic feature in the skulls of the majority of Reptiles; and no Bird has a parietal foramen. The base of the cranium is formed by the basioccipital and basisphenoid, from the latter of which proceeds the rod-like sphenoidal rostrum, representing the anterior part of the parasphenoid; while the posterior portion

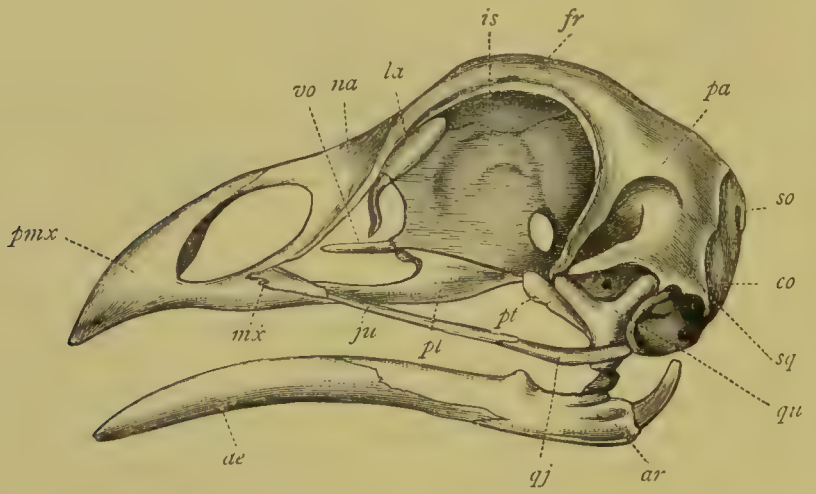


Fig. 1103.—Left lateral view of the skull of the Fowl. *de*, Dentary portion of the mandible; *ar*, Articular portion of do.; *qu*, Quadrate; *sq*, Squamosal; *eo*, Exoccipital; *so*, Supraoccipital; *pa*, Parietal; *fr*, Frontal; *la*, Lachrymal; *na*, Nasal; *vo*, Vomer; *pmx*, Premaxilla; *mx*, Maxilla; *ju*, Jugal; *qj*, Quadratojugal; *pt*, Pterygoid; *pl*, Palatine; *is*, Interorbital septum.

of the latter persists in the basitemporal plate underlying the basioccipital and basisphenoid. There is always a preorbital (lachrymonasal) vacuity between the nasal, lachrymal, and maxilla (the triangular space immediately behind the nasals in fig. 1103), as in many extinct Reptiles; and the interorbital septum is always more or less ossified. The narial aperture (fig. 1103) is lateral, and nearly always placed a short distance in advance of the orbit near the root of the beak. The greater portion of the latter is formed, as in the Ornithosauria, by the premaxillæ, which coalesce at a very early period in the middle line, and thus form a triradiate bone, giving off a median nasal and a pair of lateral maxillary processes. The pterygoids (fig. 1103) never unite together in the middle line to form a completely closed palate; and neither those bones nor the palatines ever develop inferior palatal plates to separate the narial

passage from the mouth. In this respect, therefore, the development of the Bird's skull does not attain such a specialisation as that of the existing Crocodiles. The quadrate is usually movably attached to the squamosal; and the articulation of the palatopterygoid bar to the basipterygoid processes of the sphenoidal rostrum is also a movable one, by which means the premaxillary beak can be moved to a certain extent upon the rest of the skull. The vomers are subject to great variation. They underlie the ethmosphenoidal region, and when present are connected posteriorly with the palatines, except in the Ostrich. The relations of these and the other bones of the palate form important features in Professor Huxley's classification of Birds; but since this is a subject to which the attention of the Palæontologist is but seldom directed, the reader desirous of further information must refer to other works. The jugal and the quadratojugal are slender, rod-like bones, of which the former articulates with the equally slender maxilla, and the latter by a hollow surface with the quadrate. In all existing Birds the dentary elements of the two rami of the mandible are always found welded at the symphysis into a single bone; but in the Cretaceous *Ichthyornis*, and perhaps in other Mesozoic forms, this union is imperfect. There is frequently a lateral vacuity between the dentary and splenial, like that of the Crocodilia. The angle of the mandible may be either truncated, or produced into a long recurved process, as in the Fowls (fig. 1103), Ducks, and Geese. In existing and Tertiary Birds the beak is ensheathed in horn, and is totally devoid of teeth; but rudiments of teeth have been found in some Parrots. And in certain Mesozoic forms the premaxilla, maxilla, and dentary bones were furnished with a complete series of sharp teeth. A ring of bones is always developed in the sclerotic of the eye.

In some Mesozoic Birds the vertebral centra were amphicœlous, but in all others the vertebræ exhibit certain well-marked peculiarities. Thus the neural articulations are always well developed, and the arch is invariably articulated to the centrum. The neck is usually very long; the number of its vertebræ ranging from eight to twenty-three. The atlas vertebra forms a thin ring, in which the transverse ligament may be ossified; and the axis always has the odontoid process anchylosed to it. The succeeding cervicals have either short neural spines, or no spines at all; the anterior surfaces of their centra are cylindroidal and convex from above downwards, and concave from side to side, the reverse condition obtaining posteriorly (fig. 1104). These surfaces are usually described as saddle-shaped;[1] and there may be a hæmal spine inferiorly. In the imma-

[1] The term *heterocœlous* has been proposed for this type of vertebral structure.

ture Ratitæ the cervicals have ribs articulating with an upper and a lower process, as in the Crocodilia; and in the adult (fig. 1104) these ribs anchylose to the vertebræ, and thus resemble perforated transverse processes, in which the canal (*f*) serves for the protection of the vertebral artery.[1] In adult Carinatæ these lateral arches, as they may be termed, become further modified, and develop prolongations for the protection of other parts of the vasculo-neural system. The dorsal vertebræ are liable to variation in number; their centra usually resemble those of the cervical region, but in the Penguins the articular surfaces of some may be spheroidal an-

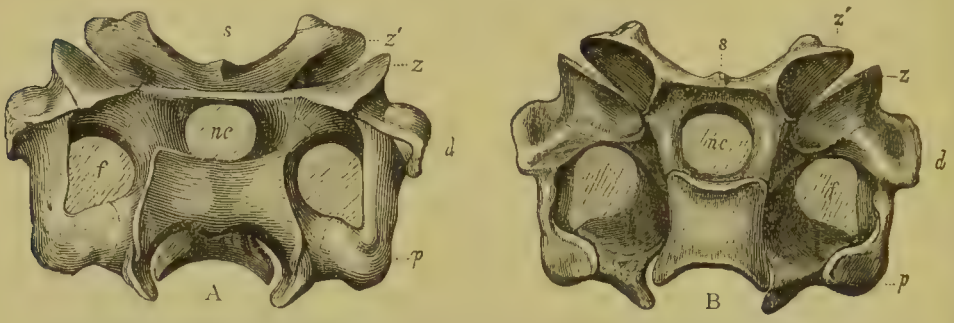


Fig. 1104.—(A) Anterior and (B) posterior views of a cervical vertebra of *Hesperornis regalis*; from the Cretaceous of North America. *s*, Neural spine; *z*, Prezygapophysis; *z'*, Postzygapophysis; *d*, Transverse process, or diapophysis; *p*, Rib-facet, or parapophysis; *nc*, Neural canal; *f*, Costal canal. (After Marsh.)

teriorly.[2] They usually have well-marked neural, and may or may not have inferior median spines; and they are in some instances anchylosed together, but in others are susceptible of a limited amount of motion. Throughout the whole dorsal series there is a well-developed transverse process from the arch for the tuberculum of the rib; while the centrum has a lateral facet for the capitulum. The method of costal articulation resembles, therefore, that obtaining in the first two dorsal vertebræ of the Crocodilia. These features are characteristic of all Birds. The dorsal vertebræ are succeeded posteriorly by a number of anchylosed vertebræ forming the sacrum. According, however, to the researches of Dr Gadow, only two or three of these vertebræ are truly sacral; those in front belonging to the lumbar, and those behind to the caudal region. Of the proper sacrals the two hindmost correspond to those of the Crocodilia, and the second of these to the single sacral of the Amphibia. The vertebræ articulating with the ilia do not develop ribs, but articulate

[1] This arrangement of the ribs is precisely similar to that occurring in certain Dinosaurs, as is shown in fig. 1071 (p. 1170).

[2] Certain Water and Wading Birds as well as Parrots, and the remarkable *Steatornis* have opisthocœlous dorsal vertebræ. The Parrots also have epiphyses to these vertebræ.

by transverse processes placed on the arch. The anchylosed series of caudals, which are sometimes termed *uro-sacral*, are in some instances, as in *Archæopteryx* and *Rhea*, followed by a considerable number of free vertebræ, but more usually by only a few, succeeded by a triangular terminal bone, known as the *pygostyle* (fig. 1106), which carries the tail feathers and glands, and represents several coalesced vertebræ. In no known Birds are ossified intercentral elements developed, with the exception of the inferior bar of the atlas vertebra. Nearly all the dorsal ribs develop tubercular and capitular processes, and some have also uncinate processes (fig. 1106, *up*). The sternum has a pair of grooves superiorly for the reception of the coracoids; and in the Ratitæ (fig. 1105) it is rhomboidal and convex, without trace of a median keel, its development taking place from two lateral centres. In the majority of Carinatæ the sternum (fig. 1106, *st*) is, however, elongated, and has a strong median keel for the attachment of the pectoral muscles. In this type two membranous vacuities frequently exist in the posterior portion, which in the dry skeleton form holes or notches, separated by bony processes, which represent divisions of the Mammalian xiphisternum. In many Carinatæ, and especially the Passerines, there are also developed a median manubrium sterni, and lateral costal processes for the attachment of the ribs. The coracoid (fig. 1106, *c*) in the Carinatæ is an elongated bone more like that of Crocodiles than that of Dinosaurs; it has no fontanelle, and articulates at an acute angle with the scapula, from which it usually remains distinct. It takes an equal share with the latter in the formation of the glenoid cavity for the head of the humerus, and at its distal end may overlap its fellow. In the Ratitæ the coracoid (fig. 1111) is, however, generally shorter and more Dinosaurian-like, and may have a fontanelle, while its long axis is either coincident or parallel with that of the adjacent portion of the scapula, with which it is invariably anchylosed in the adult. The scapula in Carinate Birds (fig. 1106, *s*) consists of a thin and narrow plate of bone, often extending backwards to a considerable length, and without any suprascapula. Occasionally an additional bony rod is developed on the outer side of the scapula. The glenoidal ends of both the scapula and coracoid are divided into a glenoidal and a clavicular process in this order. In the same order the clavicle is nearly always well developed, and fuses with its fellow to form the U-shaped furcula (fig. 1106, *fu*); but in the Ratitæ



Fig. 1105.—Sternal region of the Ostrich (*Struthio*). Reduced. *s*, Scapula; *c*, Coracoid.



Fig. 1106.—Skeleton of Eagle (*Aquila*). Reduced. *pp*, Postorbital process; *ma*, Mandible; *st*, Sternum; *dr*, Rib; *sr*, Sternal do.; *up*, Uncinate process; *co*, Pygostyle; *fu*, Furcula; *c*, Coracoid; *s*, Scapula; *h*, Humerus; *r*, Radius; *u*, Ulna; *ca*, Carpus; *mc*, Metacarpus; *d'''*, Pollex; *d*, *d'*, Phalangeals of first digit; *d''*, Do. of second do.; *p*, Ilium; *f*, Femur; *pt*, Patella; *ti*, Tibia; *fi*, Fibula; *tm*, Tarsometatarsus; *m*, First metatarsal; *pa*, Phalangeals. (After Milne-Edwards.)

the clavicles are rudimentary or wanting, and never unite to form a furcula. No Bird preserves a distinct interclavicle, although it has been thought that the median portion of the furcula represents this element—a view which, from developmental considerations, is now regarded as improbable. The furcula itself may anchylose with either the manubrium of the sternum, or with the coracoids; and very rarely both these unions occur together.

In the pectoral limb the component bones, when at rest, have been greatly altered from their original primitive position; the change being somewhat greater than that occurring in the majority of Mammals. The humerus of Carinates (fig. 1106, *h*) is expanded at both ends; the proximal extremity having a strong preaxial delto-pectoral ridge for the pectoral muscle. The pneumatic foramen occurs on the proper dorsal aspect; and at the distal extremity the prominent oblique condyle, on the outer side of the palmar aspect for the articulation of the radius, forms a very characteristic feature. In the Ratitæ this bone has less distinctive characters, and may be very small, or even absent. There is no foramen for vessels at the distal extremity of the humerus in any member of the class. The radius and ulna (fig. 1106, *u*, *r*) are always separate; the former, which is usually the larger of the two, being frequently marked with a line of tubercles for the attachment of the secondary wing-feathers. In the adult of recent Birds the free bones of the carpus are reduced to two—a radiale and ulnare; but in the Jurassic *Archæopteryx* only the radiale remains. In the latter genus the manus comprises three free metacarpals and digits; of which the first carried two, the second three, and the third four phalangeals; the terminal bone in each digit being furnished with a claw. In existing Carinate Birds the three metacarpals (fig. 1106) are more or less completely fused together; and, according to Professor Weinsheimer, ten families possess the same number (two) of phalangeals in the first digit as in *Archæopteryx*, the distal one bearing a claw; while four families also possess three phalangeals in the second digit, like *Archæopteryx*, but in only two of these families is the terminal phalangeal provided with a claw. In all existing Carinates the third digit has only a single phalangeal, without a claw. Among the Ratitæ there are three digits in *Struthio* and *Rhea*; but *Apteryx* and *Casuarius* have but a single digit, which is clawed. There is usually an interspace between the curved second and third metacarpals which may be filled up by a thin plate of bone.

The characters of the pelvis have been already briefly alluded to. The ilium (fig. 1107) is always produced considerably on both sides of the acetabulum, and in some cases, as in the Apteryx, the anterior production is very great; it articulates with the long sacrum, of which the homology has been already noticed. The ilium arches

over the greater part of the acetabulum, of which, as already mentioned, the centre is unossified, and has an external articular surface for the great trochanter of the femur termed the *antitrochanter*. The ischium forms the hinder half of the inferior part of the acetabulum, and is a moderately broad bar of bone directed downwards and backwards, or occasionally backwards (fig. 1112). In the Carinatæ (fig. 1102) it generally unites inferiorly with the ilium, by which means the upper part of the ilio-ischiatic notch is converted into a foramen; but in the Ratitæ (figs. 1107, 1112) there is no such union. In *Rhea* alone, among existing Birds, the ischia unite in a ventral symphysis. The pubis is generally a long and slender

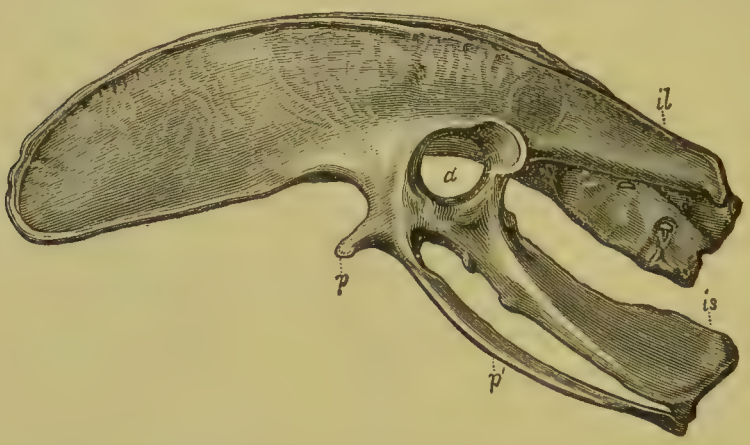


Fig. 1107.—Left side of the pelvis of the Emeu (*Dromæus*). Reduced. *il*, Ilium; *is*, Ischium; *p'*, Pubis; *p*, Pectineal process of do.; *a*, Acetabulum. (After Marsh.)

bone running parallel to the ischium, and entering into the anterior part of the lower border of the acetabulum; it frequently gives off a pectineal process (fig. 1107), which is apparently homologous with the preacetabular process of the pubis of the Ornithopodous Dinosauria. The Ostrich (*Struthio*) is peculiar among living Birds in having a symphysis pubis; while in *Archæopteryx* alone are the three pelvic bones separate. The femur is a short thick bone, with its head placed at right angles to the shaft, as in certain Dinosauria. Its condyles are large, and antero-posteriorly elongated. A patella is frequently present, and may be double. The fibula is always imperfect distally, and may be completely anchylosed to the tibia. The latter, or tibio-tarsus as it should be correctly termed, is a very characteristic bone; and is always longer than the femur. Proximally this bone is expanded and produced into an anterior cnemial process, like that of the Dinosauria, which may extend above the knee-joint; and the distal extremity (fig. 1108, A) has a trochlea-like surface, and consists of the astragalus of the tarsus, which has been completely fused with the tibia. On the anterior surface of

this bone, above the astragalus, there is frequently (as in fig. 1108, A) a bony bridge over the channel for the extensor tendons of the foot. The tarso-metatarsus (fig. 1106, *tm*) immediately succeeds the tibia; and consists proximally of the distal portion of the tarsus, with which the three middle metatarsals of the typical foot are usually completely welded to form a rod-like bone, generally terminating in three distal pulley-like surfaces for the articulation of the phalangeals. In the Penguins, however, intervals exist between the three component bones of the shaft; and in the Ostrich only two metatarsals enter into the compound element. Generally the median metatarsal at its distal end is thrust somewhat in advance of the other two (fig. 1108, B). The form of the distal condyles of this bone is very characteristic of different groups of Birds. In cases where the hallux, or first digit, is developed it is only the distal portion of its metatarsus which is attached to the posterior aspect of the tarso-metatarsus. No adult Bird has any trace of a fifth digit, and the number of digits may vary from two (Ostrich) to four (Parrots). In four-toed Birds the phalangeals generally number 2, 3, 4, 5, reckoning from the first (hallux) to the fourth digit.



Fig. 1108.—*Ibis melanocephala*. The distal portion of the right tibio-tarsus (A) and left tarso-metatarsus (B).

This increase in an arithmetical ratio of the phalangeals of the toes, in proceeding from the inner to the outer side of the foot, obtains in almost all Birds, and enables us readily to detect which digit is suppressed, when the normal four are not all present. Variations of different kinds exist, however, in the number and disposition of the toes. In many Birds—such as the Parrots—the outermost toe is turned backwards, so that there are two toes in front and two behind; whilst in the Trogons the inner toe is turned back with the hallux, and the outermost one is turned forwards. In others, again, the outer toe is normally directed forwards, but can be turned backwards at the will of the animal. In the Swifts, on the other hand, all four toes are present, but they are all turned forwards. In many cases—especially amongst the Anserine birds—the hallux is wholly wanting, or rudimentary. In the Emeu, Cassowary, Bustards, and other genera, the hallux is invariably absent, and the foot is three-toed. In the

Ostrich both the hallux and the second toe are wanting, and the foot consists simply of the third and fourth digits.

In regard to their geological distribution it should be observed that the remains of Birds are generally by no means so common in ossiferous deposits as those of Mammals. This scarcity is probably in part due to the comparatively small size and fragile nature of the bones of a large number of members of the class; and also, as Sir C. Lyell has observed, to the circumstance that "the powers of flight possessed by most birds would ensure them against perishing by numerous casualties to which quadrupeds are exposed during floods;" so that, "if they chance to be drowned, or to die when swimming on water, it will scarcely ever happen that they will be submerged so as to become preserved in sedimentary deposits, since, from the lightness of the bones, the carcass would remain long afloat, and would be liable to be devoured by predaceous animals." To these considerations must be added the absence of teeth in the great majority of Birds, whereby we are deprived of evidence which in the case of Mammals has thrown most important light upon the nature and affinity of fossil forms.

The earliest suggestion of the occurrence of Birds is afforded by impressions of huge Sauropsidan feet (fig. 1109) found in the

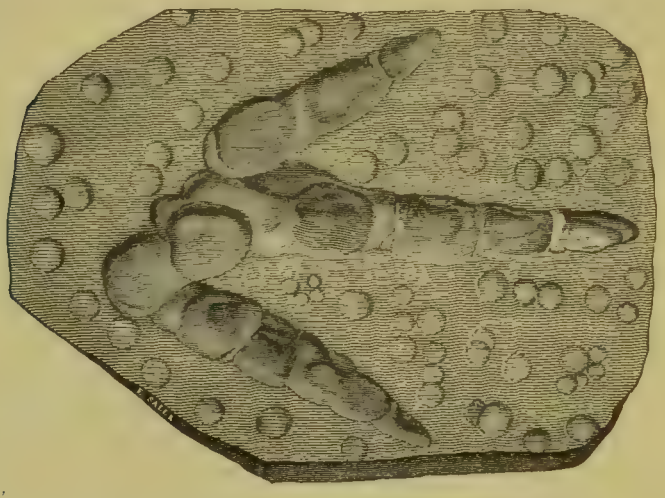


Fig. 1109.—Sauropsidan footprint, and impressions of rain-drops; from the Trias of the Connecticut Valley. Reduced.

reputed Triassic sandstone of the Connecticut Valley in the United States. These impressions were evidently made either by Ornithopodous Dinosaurs, or by Ratite Birds; and the occurrence of certain reptilian bones in the same deposits indicates that at least some of them are probably of Dinosaurian origin. The absence of the

impression of a tail among some of these tracks renders it, however, not altogether improbable that a few of them may be due to Birds.

Apart from the foregoing extremely doubtful evidence, the earliest undoubted occurrence of Birds is in the Upper Jurassic, where we find *Archæopteryx* in the Kimeridgian of Bavaria. *Laopteryx*, from the Jurassic of North America, which was described as a Bird, is more probably a Reptile. Of the extremely generalised nature of the former mention is made in the next chapter. In the Cretaceous system of North America we find not only the remarkable toothed Birds, which were already differentiated into the Ratite and Carinate modifications; but there were apparently others more nearly allied to existing types. Bird-remains also occur rarely, and in a very fragmentary state, in the Upper Cretaceous of Europe. With the Eocene we enter upon an Avian fauna of a decidedly modern type; and at the period of the Lower Miocene the greater number of existing suborders were well represented.

We are at present to a great extent in the dark as to the manner in which Birds branched off from the primitive Sauropsidan stock; but it is pretty evident that the Dinosauria are those Reptiles most nearly related to Birds, and that the Ornithosauria are totally out of the direct ancestral line,—the curious resemblance which they present to Carinate Birds being apparently solely due to their somewhat similar mode of life.

In respect to the mode of origin of the Ratite and Carinate modifications of Bird-structure, we may quote from an admirable article by Professor A. Newton, who observes that—"First of all we find that while Birds still possessed the teeth they had inherited from their Reptilian ancestors, two remarkable and very distinct types of the class had already made their appearance, and we must note that these two types are those which persist at the present day, and even now divide the class into the Ratitæ and Carinatæ. Furthermore, while the Ratite type (*Hesperornis*) presents the kind of teeth, arrayed in grooves, which indicate (in Reptiles at least) a low morphological rank, the Carinate type (*Ichthyornis*) is furnished with teeth set in sockets and showing a higher development. On the other hand, this early Carinate type has vertebræ, whose comparatively simple biconcave form is equally evidence of a rank unquestionably low; but the saddle-shaped vertebræ of the contemporary Ratite type as surely testify to a more exalted position. Reference has been already made to this complicated if not contradictory state of things; the true explanation of which seems to be out of reach at present. It has been for some time a question whether the Ratite is a degraded type descended from the Carinate, or the Carinate a superior development of the Ratite type." The Professor, after noticing that many Zoologists have adopted the former view, proceeds to observe that, before the question can be answered, a reply must be given to the following question—"Was the first animal which any one could properly call a 'Bird,' as distinguished from a 'Reptile,' possessed of a keeled sternum or not? Now Birds would seem to have been differentiated from Reptiles while the latter had biconcave vertebræ, and teeth whose mode of attachment to

the jaw was still variable. There is no reason to think that at that period any Reptile (with the exception of Pterodactyles, which, as has already been said, are certainly not in the line of Birds' ancestors) had a keeled sternum. Hence it seems almost impossible that the first Bird should have had one; that is to say, it must have been practically of the Ratite type. Professor Marsh has shown that there is good reason for believing that the power of flight was gradually acquired by Birds, and with that power would be associated the development of a keel to the sternum, on which the volant faculty so much depends. . . . Thus the Carinate type would, from all we can see at present, appear to have been evolved from the Ratite." After observing that embryological and distributional facts afford support to this view, Professor Newton continues as follows: "No doubt the difficulty presented by the biconcave vertebræ of the earliest known representative of the Carinate type is a considerable obstacle to the view just taken. But Professor Marsh has shown that in the third cervical vertebra of *Ichthyornis* 'we catch nature in the act as it were' of modifying one form of vertebra into another, for this single vertebra in *Ichthyornis* is in vertical section 'moderately convex, while transversely it is strongly concave, thus presenting a near approach to the saddle-like articulation;' and he proceeds to point out that this specialised feature occurs at the first bend of the neck, and, greatly facilitating motion in a vertical plane, is 'mainly due originally to its predominance.' The form of the vertebræ would accordingly seem to be as much correlated with the mobility of the neck as is the form of the sternum with the faculty of flight. If, therefore, the development of the saddle shape be an indication of development, as well may be the outgrowth of a keel." In conclusion, the Professor observes that the question must be regarded as still unsettled, although his own opinion is strongly in favour of the Ratite being the earlier type.

On the other hand, Dr Gadow, in a communication of later date, concludes that the Ratitæ were most probably descendants of Birds which formerly possessed the power of flight; this view being said to be supported by the structure of the wings, and the nature of the feathers of the young.

In the following chapter a brief summary is given of the chief divisions of Birds, with mention of those families known to be represented in a fossil state. It would, however, exceed the limits of this work to give even the leading osteological characters of such families, since, owing to the great general similarity in the structure of all Carinate Birds, such characters could only be indicated by the introduction of a great mass of detail.

It should also be observed that the majority of writers rank the three primary divisions of Birds as subclasses, and the secondary divisions as orders, with the proviso that such orders are of very different value from those of Reptiles. With the object of avoiding this inequality the view of Professor Huxley, who has termed the primary divisions orders and the secondary ones suborders, has been followed in this work.

CHAPTER LVII.

CLASS AVES.

Orders Saururæ, Ratitæ, and Carinatæ.

Order I. Saururæ.—This extinct order is represented only by *Archæopteryx*, and may be characterised by the metacarpals being separate, and by the tail being longer than the body, and not terminating in a pygostyle.

Family Archæopterygidæ.—*Archæopteryx*, including birds of about the size of the common Rook, is found in the lithographic limestones of Solenhofen, near Pappenheim, in Bavaria, which are the representatives of the lower part of the English Kimeridge Clay. This genus was first made known by the impression of a single feather, to which the late Professor H. von Meyer gave the name *A. lithographica*. Subsequently the greater part of a skeleton, with impressions of the feathers of the wings and tail (fig. 1110), was obtained, which Sir R. Owen named *A. macrura;* while recently a second skeleton has been found which some writers regard as indicating a distinct species from the first. Of these two skeletons the former is preserved in the British and the latter in the Berlin Museum. Professor Carl Vogt, who first described the Berlin specimen, regarded *Archæopteryx* as a Reptile; but there can be no hesitation in classing it among the Birds. The jaws were furnished with teeth; the vertebræ were biconcave; and there was a well-ossified sternum, of considerable breadth, and probably provided with a carina. In the manus the three metacarpals remained distinct; and there were also three separate digits, each of which was terminated by a claw. In the pelvis the three component elements exhibit the Reptilian character of remaining distinct throughout life; and it is thought probable that the ischia united in a ventral symphysis. The distal portion of the fibula is placed in front of the tibia; and the metatarsals were either separate or but very imperfectly united together. The tail, again (fig. 1110),

differs from that of all other known Birds in that it consists of a series of long vertebræ, gradually tapering to the extremity, and each of which carries a pair of feathers. From the absence of impressions of feathers in the region of the body, it has been thought that only the wings and tail had these appendages; but it is far more probable that the feathers had fallen from the body as it lay on the old sea-shore, while those of the wings and tail still

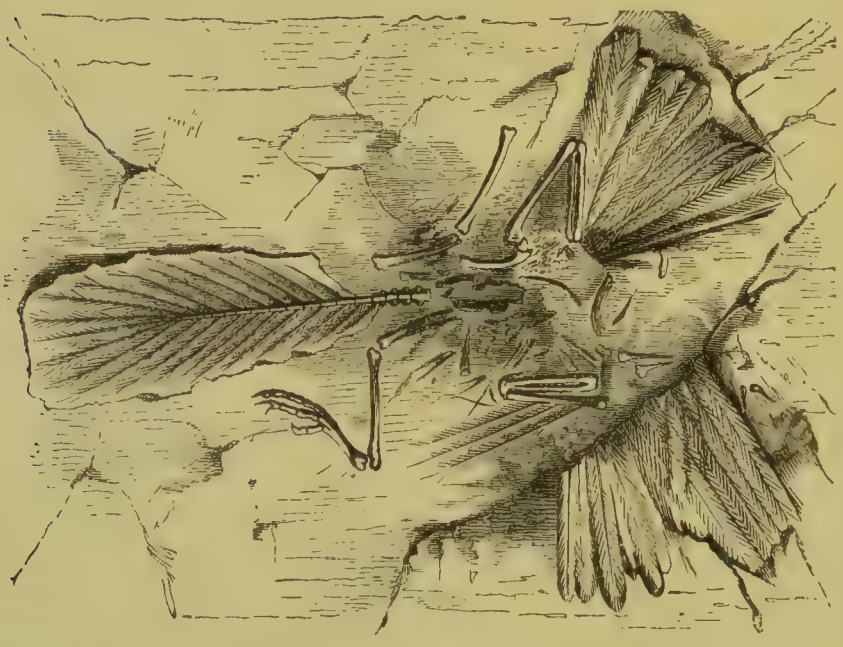


Fig. 1110.—Part of the skeleton, with impressions of the feathers of the wings and tail, of *Archæopteryx macrura*; from the lithographic limestone of Bavaria. Reduced.

adhered to their attachments. In the figure of the British Museum specimen of *A. macrura* (fig. 1110) the head is not shown; but it exists in an imperfect state of preservation in the slab. Till we know more of the other Birds of the Jurassic, the true relationship of *Archæopteryx* to existing forms cannot be determined.

Order II. Ratitæ.—The Ratitæ, or Struthious Birds, differ from the preceding order by the anchylosis of the metacarpals (when present) and the short tail, which may terminate in a pygostyle. They are further characterised by the sternum (figs. 1105, 1111) being devoid of a keel; by the long axes of the adjacent portions of the scapula and coracoid being approximately in the same line (fig. 1111), or at least forming an exceedingly obtuse angle at their junction; by the wings being useless for flight; and by the peculiar characters of the pelvis (figs. 1107, 1112), which have been already mentioned. There are, moreover,

important osteological characters connected with the palatal aspect of the skull which cannot be noticed here; and some other features have been mentioned in the preceding chapter. The massive bones are frequently filled with marrow. In all forms the fibula remains quite distinct from the tibia; and the distal end of the latter fre-

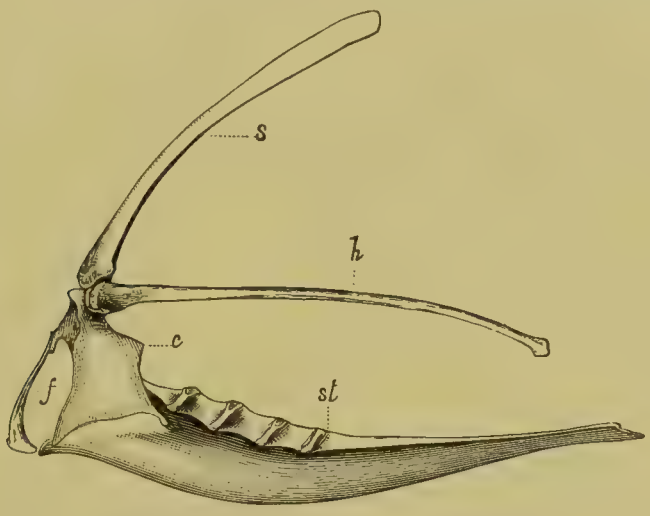


Fig. 1111.—Left half of the pectoral girdle and sternum of *Hesperornis regalis;* from the Cretaceous of North America. Reduced. *s*, Scapula; *h*, Humerus; *c*, Coracoid; *f*, Clavicle; *st*, Sternum. (After Marsh.)

quently has no bridge over the extensor tendons. In all existing forms the plumage presents the remarkable peculiarity that the barbs of the feathers, instead of being connected with one another by hooked barbules, as is usually the case, are remote and disconnected from one another, presenting some resemblance to hairs.

This order embraces the largest known members of the whole



Fig. 1112.—Left half of the pelvis of *Hesperornis regalis;* from the Cretaceous of North America. Reduced. Letters as in fig. 1107. (After Marsh.)

class; and from the scattered distribution of both its existing and fossil representatives is evidently an extremely ancient type. Its relations to the Carinatæ have been already alluded to in the preceding chapter. The order may be divided into two series, according to the presence or absence of teeth.

Toothed Series.—In this extinct series teeth are present in the jaws.

Suborder 1. Odontolcæ.—The type and only known representative of this suborder is *Hesperornis*, of the Cretaceous of North America. In this remarkable Bird (fig. 1113) the jaws (fig. 1117) were provided with a series of sharp-pointed teeth, sunk in a deep continuous groove; but the anterior portion of the upper jaw was



Fig. 1113.—Skeleton of *Hesperornis regalis;* from the Cretaceous of North America. About one-tenth natural size. (After Marsh.)

edentulous, and probably sheathed in a horny covering like that of existing Birds. Various parts of the skeleton are represented in figs. 1111, 1112, and 1117.

In its whole skeletal organisation *Hesperornis* conforms strictly to the existing Ratite type; but there were four digits in the pes (all of which were directed forwards), and Professor Marsh believes that it was of aquatic habits, and compares it to a swimming Ostrich. According to the description of the same authority, the tail consists of about twelve vertebræ, of which the last three or four are amalgamated to form a flat

terminal mass, there being at the same time clear indications that the tail was capable of an up and down movement in a vertical plane, thus probably fitting it to serve as a swimming-paddle or rudder. The vertebræ of the cervical and dorsal regions are of the ordinary ornithic type. The legs were powerfully constructed, and the feet were adapted to assist the bird in rapid motion through the water. The known remains of the typical *Hesperornis regalis* (fig. 1113) prove it to have been of larger dimensions than any of the aquatic members of the class with which we are acquainted at the present day. It appears to have stood between five and six feet high, and its inability to fly is fully compensated for by the numerous adaptations of its structure to a watery life. Its teeth prove it to have been carnivorous in its habits, and it probably lived upon fishes. A second species of this genus occurs in the same deposits, and is known as *Hesperornis crassipes;* but it was originally regarded as belonging to a distinct genus, and named *Lestornis*.

Toothless Series.—This series, which includes the whole of the remaining forms, is characterised by the absence of teeth.

Suborder 2. Æpyornithes.—This suborder is represented by a single family, the *Æpyornithidæ*, of the Pleistocene of Madagascar. The one known genus, *Æpyornis*, is characterised by the shortness of the beak; the small wings; the absence of a tibial bridge over the extensor tendons; and the presence of a hallux in the pes. The typical *Æ. maximus* appears to have attained dimensions rivalling those of the largest species of *Dinornis* (to be shortly mentioned); and eggs have been found in association with the bones measuring fourteen inches in diameter, and computed to be equal in capacity to three eggs of the Ostrich. At least two smaller species of the same genus occur in the Madagascar Pleistocene.

Suborder 3. Apteryges.—The members of the second suborder of this series are confined to New Zealand, and may all be included in the family *Apterygidæ*, which is now represented by the Kiwis or *Apteryx* (fig. 1114). They are distinguished from all other existing members of the order by their extremely long and slender beak, which is adapted for probing the soft marshy ground which they frequent in search of worms and other food. Omitting mention of the peculiar cranial and sacral characters, it may be observed that the wing has a comparatively short humerus, and not more than one ungual phalangeal. The tibia is furnished with a bony bridge over the extensor tendons; and there is a hallux to the pes. The feathers have no aftershafts. The Kiwis are essentially nocturnal in their habits. Remains of the existing species of *Apteryx* are found fossil in the Recent and Pleistocene deposits of New Zealand; while some much larger bones from the same deposits have been described by the late Sir Julius von Haast under the name of *Megalapteryx*, which appears to have been a giant form closely allied to the existing genus.

Suborder 4. Immanes.—This recently extinct group, like the last, is almost peculiar to New Zealand, and comprises some of the largest known Birds. The beak (fig. 1115) is short; the wings are either very small or totally wanting; the tibia has a distal bridge over the extensor tendons; and in some instances there was a hallux in the pes. The characters of the skull and pelvis come nearest to those of the next suborder, and the feathers have after-shafts. This group has been divided into the *Dinornithidæ* and *Palapterygidæ*, on account of the absence of the hallux in the former. Although this distinction has been doubted by some writers, who consider that *Dinornis* had a hallux, it appears to be



Fig. 1114.—*Apteryx australis*, New Zealand.

a valid one. Apart, however, from this point, according to the late Sir J. von Haast, the *Palapterygidæ* were provided with rudimentary wings, while in the *Dinornithidæ* those appendages were totally absent. Mr De Vis has described some bird-bones from the Pleistocene of Queensland under the name of *Dinornis queenslandiæ*; this being the only instance in which remains of this group have been recorded elsewhere than in New Zealand. Sir J. von Haast proposes to divide the *Palapterygidæ* into *Palapteryx* and *Euryapteryx*, and the *Dinornithidæ* into *Dinornis* and *Mionornis*.

The first evidence of the existence of this marvellous group was afforded by a fragment of the shaft of one of the bones of the leg brought to Sir

Richard Owen at a time when the existence of such huge Birds was totally unsuspected, and upon which evidence he founded the type genus. That the Moas, as these Birds are termed by the Maories of New Zealand, have only been exterminated at a comparatively recent date is proved by the occurrence of nearly entire skeletons with the skin and feathers still adhering to them, as well as by fragments of the eggs retaining their original pale-green colour. The largest species is *D. maximus*, of which the total height was about ten feet, the tibia measuring a yard in length. Another species, *D. elephantopus* (fig.



Fig. 1115.—Skeleton of *Dinornis elephantopus*; from the Pleistocene of New Zealand. Greatly reduced. (After Owen.)

1115), although not standing more than about six feet in height, was of even more massive construction, the toe-bones almost rivalling those of the elephant in size. The number of species described is very large.

Suborder 5. Megistanes.—The Emeus and Cassowaries are characterised by certain structural peculiarities in the base of the short cranium; by the moderately long humerus; the presence of only one complete digit in the manus, which is furnished with a claw; the absence of a ventral symphysis in the pubes or ischia;

the want of a bridge over the extensor tendons in the tibia; and the suppression of the hallux. The family *Dromœidæ* is represented by the existing Emeu (*Dromœus*) of Australia, and also by fossil species in the Pleistocene of the same country. *Dromornis*, from the latter deposits, is an extinct genus referable to this family. The characters of the pelvis of the existing genus are shown in fig. 1107. The *Casuariidæ*, now characteristic of the Australasian region, have not hitherto been definitely recorded in a fossil state; although it is possible that a phalangeal from the Indian Siwaliks may be referable to this family.

Suborder 6. Rheæ.—The *Rheidæ*, which alone constitute this group, and are confined to South America, differ from the Megistanes by the structure of the palate, as well as by the longer humerus, the presence of three digits (of which two are clawed) in the manus, by the ventral union of the ischia, and the absence of an aftershaft to the feathers. Remains of *Rhea*, which are referred to the existing species, occur in the Pleistocene cave-deposits of Brazil.

Suborder 7. Struthiones.—The family *Struthionidæ* is the sole representative of this suborder; the only existing species being the Ostrich (*Struthio camelus*), which is now confined to Africa and Arabia, although it formerly ranged into Persia, and probably also to Baluchistan and the north-west frontier of India. In addition to the characters of the palate, *Struthio* differs from *Rhea* by the union of the pubes in a ventral symphysis, and also by the suppression of the second digit of the pes, in consequence of which the distal end of the tarso-metatarsus has but two trochleæ. This genus is represented in the Pliocene Siwaliks of India, and also in the Lower Pliocene of the Isle of Samos, in the Turkish archipelago, by remains referred to two species. These forms, which may be specifically the same, appear closely allied to the existing Ostrich. An egg, from Tertiary beds near Gallipoli—the ancient Chersonese—described under the name of *Struthiolithus*, probably belongs to the existing genus, and very likely to the species occurring at Samos. These fossil forms point to the conclusion that the original home of the genus was probably in Asia.

Suborder 8. Gastornithes.—The *Gastornithidæ*, whose remains occur in the Lower Eocene of Europe, were large Birds which may probably be classed with the Ratitæ, and are apparently entitled to distinct subordinal rank. Their tibia agrees with that of the Apteryges and Immanes in having a bony bridge over the extensor tendons, but makes a curious approximation in shape to that of certain members of the Carinate suborder Anseres. The wings were somewhat larger than in the Ostrich; and the cranium, which is estimated to have been fifteen inches in length, had the alveolar margins of the jaws serrated, as in the genus *Odontopteryx* (fig.

1121). Remains of *Gastornis* have been recorded from Meudon, near Paris, from Rheims, and from Croydon, and have been referred to four species. The huge *Diatryma*, from the Lower Eocene of North America, appears to be closely allied to, if not identical with, *Gastornis*. Bird-bones from the Tertiary of South America, described by Dr Moreno under the name of *Mesembriornis*, and compared to the Anseres, probably indicate a member of this group, since they are fully as large as the corresponding bones of the Ostrich.

Here also may be noticed an imperfect cranium from the London Clay, described by Sir R. Owen as *Dasornis*, and regarded by him as pertaining to a Ratite Bird. And it may be also mentioned that an imperfect limb-bone from these deposits, which has been named *Megalornis*, may perhaps belong to the same genus.

ORDER III. CARINATÆ.—The third order, which is now by far the most numerously represented, is generally characterised by the presence of a median keel to the sternum, and by the long axes of the adjacent portions of the scapula and coracoid forming at their junction an acute or slightly obtuse angle, as well as by the upward extension of the ischium towards the ilium (fig. 1102). In most cases the wings are adapted for flight, but in some instances they have become atrophied, while in others they are modified into swimming organs.

There is still considerable diversity of views obtaining among Ornithologists as to the classification of this order, and all such schemes must consequently be regarded as more or less provisional. In the present work the classification adopted by Mr P. L. Sclater is followed in the main, although certain modifications suggested by Professor Newton have been incorporated.

Before noticing those fossil forms which are susceptible of being placed in definite groups it will be advisable to mention briefly certain remains of which the affinity has not yet been determined, although it is probable that at least the majority should find a place in the present order. As to *Laopteryx*, of the Upper Jurassic of North America, there appears, as already mentioned, to be considerable doubt whether it is really Avian at all. In the Cretaceous of the same country we have *Apatornis*, *Graculavus*, *Laornis*, *Palæotringa*, and *Telmatornis*; many or all of which probably belong to the first suborder. In England the oldest known bird-remains occur in the Cambridge Greensand, and have been named *Enaliornis*, although it is quite probable that they may indicate more than one genus. Some of these vertebræ have more or less flattened centra; while the tarso-metatarsus, in which the fusion of the component elements is incomplete, is compared to that of the existing *Colymbus* and also to that of *Ichthyornis*, and it is highly prob-

able that these Birds were allied to the latter genus. The bones from the Cretaceous of Europe described as *Palæornis*, *Cimoliornis*, and *Cretornis*, belong to Ornithosauria.

In the Tertiary we have *Eupterornis* and *Remiornis* from the Lower Eocene of Rheims; while the Upper Eocene (Lower Oligo-

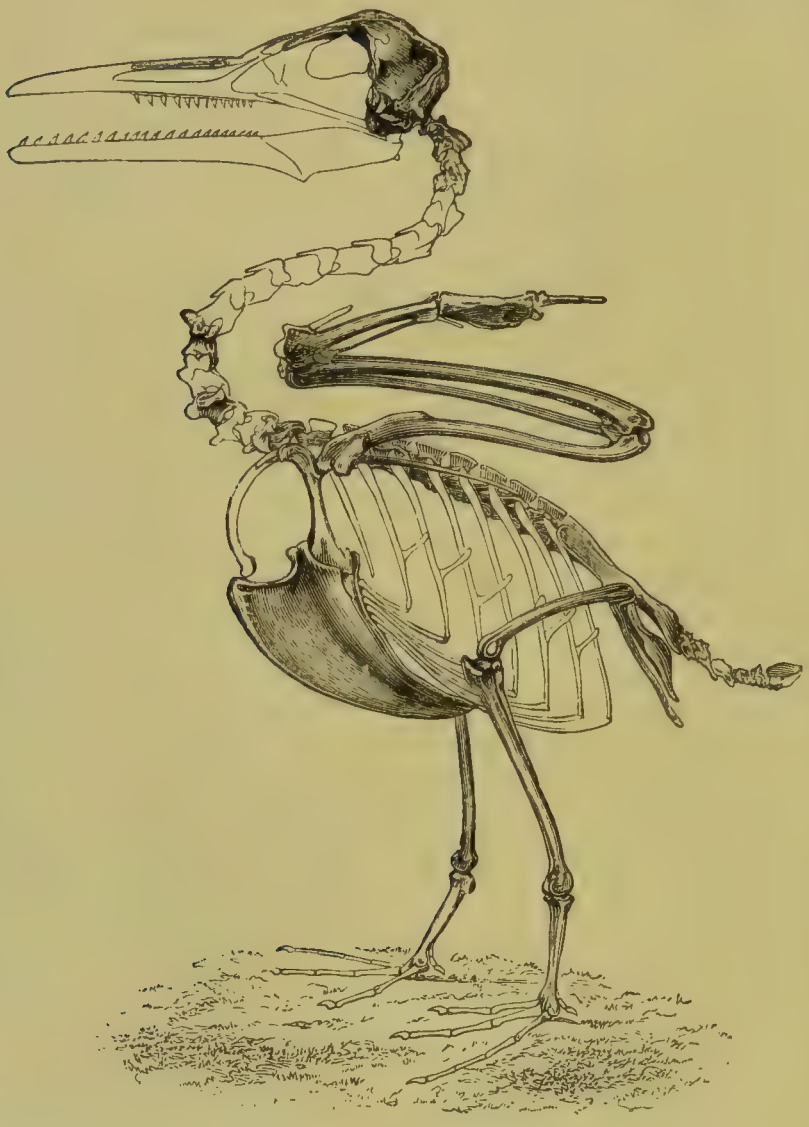


Fig. 1116.—Restoration of the skeleton of *Ichthyornis dispar;* from the Cretaceous of North America. Reduced. (After Marsh.)

cene) of Hampshire has yielded *Macrornis*, and the Lower Miocene (Upper Oligocene) of the same county *Ptenornis*.

Toothed Series.—This extinct series is characterised by the presence of teeth, and typically of amphicœlous vertebræ.

Suborder 1. Odontormæ.—The one suborder which is the only known representative of this series contains the family *Ichthyornithidæ*, from the North American Cretaceous, of which *Ichthyornis* is the only definitely known genus, although it is highly probable that *Apatornis*, and some of the other Cretaceous forms already mentioned, may also belong to this or an allied family. The teeth of *Ichthyornis* (fig. 1117, *a*) are comparatively large, and are set in distinct sockets; while the centra of the vertebræ are amphicœlous. There were about twenty teeth in each jaw, which are directed obliquely backwards. The rami of the mandible were but loosely united; and it is probable that the jaws were not sheathed in horn. The adult of the typical *I. dispar* (fig. 1116) was about equal in size to a Rock-pigeon; and in all essential features of its organisa-

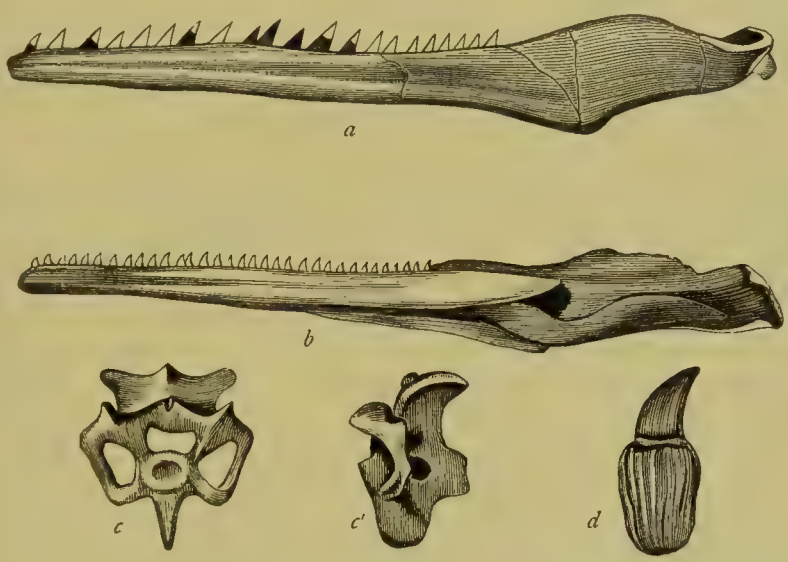


Fig. 1117.—*a*, Left ramus of the mandible of *Ichthyornis*, slightly enlarged; *b*, Do. of *Hesperornis*, about one-fourth natural size; *c*, *c'*, Anterior and lateral aspects of cervical vertebra of *Ichthyornis*, twice natural size; *d*, Tooth of *Hesperornis*, twice natural size. (After Marsh.)

tion this genus conforms so exactly with the existing Carinate type, that there appears every reason for including it in the same order, rather than following Professor Marsh's view of placing it, together with *Hesperornis*, in a separate order under the name of Odontornithes.

Toothless Series.—In this series, which comprises all existing Carinates, no teeth are ever functionally developed, although germs occur in the young of one group.

Suborder 2. Crypturi.—The Tinamous (*Tinamus*, &c.) which constitute this suborder, show more signs of affinity in the structure of their pelvis and skull to the Ratitæ, than is exhibited by any

other group of this order. They are confined to the New World, and are represented in a fossil state by remains of existing species of *Crypturus*, *Nothura*, *Tinamus*, and *Rhynchotus*, in the Pleistocene cave-deposits of Brazil.

Suborder 3. Impennes.—The Penguins (*Aptenodytes*, &c.) of the Antarctic regions form a peculiarly interesting and well-defined group of Birds, in which the wings are modified for swimming, and the component bones of the tarso-metatarsus are separated by vacuities. It has recently been proposed that the Impennes should form a primary group of equivalent rank with the Carinatæ, under the name of Eupodornithes. Unfortunately scarcely anything is known of their palæontological history, the only fossil type being *Palæeudyptes* from the Tertiary of New Zealand.

Suborder 4. Tubinares.—The Petrels, or *Procellariidæ*, are the only family of this group. The only known fossil representatives are members of the existing genus *Puffinus* (Shearwater), which have been recorded from the Lower Miocene of Allier, in France, and also from the Miocene of the United States.

Suborder 5. Pygopodes.—According to the opinion of Professor Newton this and the two following groups should be regarded merely as sections of a single suborder, but since no name has been proposed for this larger group the three divisions are retained. Of the Pygopodes, the *Alcidæ*, or Auks, include the Great Auk (*Alca impennis*) of the Arctic regions, which now appears to be totally extinct, but of which the remains are found abundantly in the peat and other superficial deposits of northern Europe. Remains referred to the genus *Uria* (Guillemots) are found in the Upper Pliocene of Italy; and Guillemots also occur in the Tertiary of the United States, where they have been described under the name of *Catarractes*. In the *Colymbidæ*, which includes the Grebes and Divers, remains of the Red-throated Diver (*Colymbus glacialis*) are found in the Pleistocene deposits of Mundesley, in Norfolk; while the extinct *Colymboides* of the Lower Miocene of Allier appears to be an allied form.

Suborder 6. Gaviæ.—Of the *Laridæ* (Gulls and Terns) a species of *Larus* occurs in the Allier Miocene; while *Hydrornis* of the latter deposits may probably be referred to the same family. An undetermined genus from the London Clay may perhaps be also referable to the present group.

Suborder 7. Limicolæ.—The Limicolæ are somewhat abundantly represented in Tertiary deposits; the subaquatic habits of many of its members being probably conducive to the preservation of their remains. In the family *Scolopacidæ* the genus *Numenius* (Curlew) is recorded from the Middle Miocene of Gers, in France, and the Pliocene of Italy; *Limosa* (Godwit) occurs in the Upper

Eocene (Lower Oligocene) of Montmartre; *Totanus* (Redshank) in the Allier Miocene and the Pliocene of the Val d'Arno, in Tuscany; and *Tringa* (Knot and Dunlin) probably in the Montmartre, and certainly in the Allier beds, and the equivalent deposits of the Mayence basin. *Elorius* is an extinct genus from Allier, probably allied to *Limosa*. The Woodcock (*Scolopax rusticola*) has left its remains in the Pleistocene of Westphalia; and a species of *Himantopus* (Stilt) is found in the Allier Miocene. In the family *Charadriidæ* (Plovers) a species of the type genus *Charadrius* occurs in the Upper Eocene of Colorado; while the genus *Camascelus* (with which *Dolichopterus* is not improbably identical) is known from the Lower Miocene beds of Ronzon, in France.

Suborder 8. Alectorides.—The Alectorides form a somewhat ill-defined group, which is taken by Mr Sclater to include the *Otididæ*, although Professor Newton regards the latter as more nearly allied to the Gaviæ and Limicolæ. The family *Gruidæ*, or Cranes, is represented by the type genus *Grus* in the Pleistocene of Europe, India, and the United States, and also in the Lower Pliocene Pikermi beds of Greece, and the Miocene of Allier. Allied extinct genera are *Palæogrus* of the Eocene of Italy, and *Aletornis* of that of Wyoming. The *Otididæ* are represented by a species of Bustard (*Otis*) in the Allier Miocene.

Suborder 9. Fulicariæ.—This suborder comprises the Rails, Coots, Water-hens, etc.; all of which are included in the single family *Rallidæ*, and are of more or less aquatic habits. Birds referred to the type genus *Rallus* (Rail) occur in the Montmartre Eocene, the Miocene of Allier and Gers, and the Italian Pliocene. Remains of *Gallinula* (Water-hen) are recorded from the Pleistocene beds of Brazil and Queensland; in both of which deposits we meet with others referred to *Porphyrio* (Purple Water-hen)—a genus now widely distributed over the warmer regions of the globe. An extinct species of Coot (*Fulica*) has also been described from the Queensland Pleistocene. *Notornis*, which occurs in the Pleistocene of New Zealand and was also found living some years ago, is a large Rail allied to the Australian *Tribonyx*; while *Aptornis*, which is a very large form from the same deposits totally incapable of flight, is more nearly related to the existing *Ocydromus* of New Zealand. *Aphanapteryx* (*Erythromachus*) from the Pleistocene of Mauritius and Rodriguez is another large Rail allied to *Ocydromus*. Lastly, *Gypsornis*, of the Montmartre Eocene, is considered to be the earliest representative of this family.

Suborder 10. Gallinæ.—The Gallinæ form a large group of Birds mostly living to a considerable extent on the ground, and of comparatively stout build. They comprise the families *Megapodidæ* (Megapodes), *Cracidæ* (Curassows and Guans), *Phasianidæ*

(Pheasants, Turkeys, etc.), and *Tetraonidæ* (Grouse). The Gallinæ together with the following group of Columbæ were formerly bracketed together under the name of Rasores, and it is by no means certain that the departure from this arrangement is an advisable one. The skull (fig. 1103, p. 1210) has peculiar palatal features, a sharp curved beak, and a recurved process to the angle of the mandible. Many of the genera of Gallinæ (especially the males) are characterised by the presence of one or more strong bony spurs on the inner side of the tarso-metatarsus (fig. 1118). The first two families are at present unknown in a fossil condition. In the *Phasianidæ*, however, the typical genus *Phasianus* occurs in the Allier and Gers Miocene deposits, and also in the Lower Pliocene of Pikermi; *Francolinus* (Francolin) is represented by remains of existing species in the Pleistocene of Southern India (fig. 1118); *Coturnix* (Quail) in the Montmartre Eocene gypsum; the extinct *Palæortyx* in both the latter deposits and the Isère and Allier Miocene beds, the so-called *Palæoperdix* of the Mayence Miocene being probably identical; while a species of *Gallus*, somewhat larger than the existing Indian *G. Sonnerati*, is found in the Pikermi Pliocene. From the Miocene of the United States a Turkey (*Meleagris antiqua*) has been recorded, and is described as equal in size to the living species now characteristic of America. In the *Tetraonidæ* remains of the living Capercaillie (*Tetrao urogallus*) occur in the Norfolk Forest-bed; while an extinct species of the same genus has been described from the Upper Eocene of Languedoc. Remains of the existing Willow Grouse (*Lagopus albus*) are found in the Pleistocene of Westphalia.



a *b*

Fig. 1118.—*Francolinus pondicerianus*. The left tarso-metatarsus; from the Pleistocene of Madras. *a*, Posterior; *b*, Anterior aspect.

Suborder 11. Columbæ.—This group is taken to include the existing Sand-grouse (*Pteroclidæ*), and the Pigeons (*Columbidæ*). In the first-named family a species of the type genus *Pterocles* has been described from the Allier Miocene. The *Columbidæ* are known by a species referred to *Columba* from the last-named deposits, as well as by another provisionally referred to the same genus from the Pleistocene of Rodriguez. Of especial interest is a tarso-metatarsus from the Pleistocene of Queensland described by Mr De Vis under the name of *Progoura*, and regarded as indicating a bird allied to the Crowned-Pigeons (*Goura*) of New Guinea. *Goura* shows some signs of affinities to the *Phasianidæ*, and these resemblances are said to be more marked in *Progoura*, which is double the

size of the existing forms. Here also may be placed the now extinct family *Didida*, represented by the Dodo (*Didus ineptus*) of Mauritius, and the Solitaire (*Pezophaps solitaria*) of Rodriguez.

Of these two singular birds, the Dodo formerly inhabited Mauritius in great numbers, but the last record of its occurrence dates from the year 1681. It was a large and heavy bird (fig. 1119), bigger than a swan, and entirely unlike the pigeons in general appearance. The wings were rudimentary and completely useless as organs of flight. The legs were short and stout, the feet had four toes each, and the tail was extremely



Fig. 1119.—Skeleton of the Dodo (*Didus ineptus*), restored. (After Owen.

short, carrying, like the wings, a tuft of soft plumes. The beak (unlike that of any of the *Columbæ* except the little *Didunculus strigirostris*) was arched towards the end, and the upper jaw had a strongly-hooked apex, not unlike that of a bird of prey. The frontal region of the skull was greatly elevated and tumid, from the excessive development of cellular cavities between the two tables of the skull, and the actual brain-case was very small in proportion to the size of the cranium. In many respects allied to the Dodo, and, like it, incapable of flight, was the Solitaire, of which the last recorded appearance was in the year 1693. The Solitaire had longer legs and neck than the Dodo, the bill was less strongly arched, its forehead flatter, and there was developed

upon the radial side of the metacarpus an extraordinary spherical callus-like mass of bone, about as large as a musket-ball, and with a roughened surface. This singular callosity is much more developed in certain individuals—supposed to be males—than in others, which we may presume to be females; it was doubtless covered during life by a horny integument, and seems to have been used as an offensive weapon. Both these Birds are known to us by nearly entire skeletons obtained recently from the islands which they inhabited; and of the Dodo we have also a few remains belonging to entire specimens once preserved in our museums, which were unfortunately allowed to fall into decay, from apparent ignorance of their priceless value.

Remains of existing species of several genera of *Columbidæ* are found in the Pleistocene cave-deposits of Brazil.

Suborder 12. Anseres.—The Anseres, or Goose-like Birds, form a well-defined subordinal group, characterised by peculiar features, in the palatal region of the skull, and by the perfectly webbed feet; the beak being generally broad and spatulate, and the angle of the mandible with a recurved process (fig. 1120). All the existing members of this group are referred to the family *Anatidæ*, which is, however, split up into several subfamilies. A peculiar subfamily is represented by the living *Cereopsis*, of Australia; allied to which is the much larger extinct *Cnemiornis*, of the Pleistocene of New

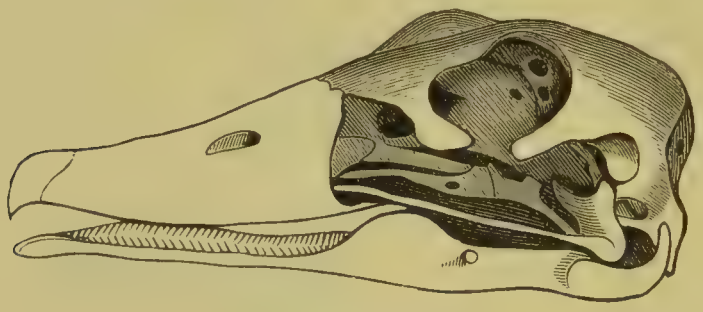


Fig 1120.—Skull of Spur-winged Goose (*Plectropterus gambensis*). Reduced.

Zealand, which was quite incapable of flight. In the subfamily *Anserinæ*, remains of the Grey-Lag Goose (*Anser cinereus*) occur in the European Pleistocene. The *Cygninæ*, or Swans, are represented by the extinct *Cygnus Falconeri*, from the Pleistocene cave-deposits of Malta. In the *Anatinæ* (Ducks) an extinct species of Tree-duck (*Dendrocygna*) is recorded from the Pleistocene of Queensland. Remains of the Wild-duck (*Anas boscas*) occur in the Pleistocene of Europe; *A. atavæ* and *A. cygniformis* are found in the Middle Miocene of Bavaria, the latter species being nearly as large as a Swan; *A. œningensis*, from the Upper Miocene of Switzerland; *A. lignifila*, from the Middle Miocene of Italy; and *A. Blanchardi*, from the Allier Miocene. Remains of the Shoveller

Duck (*Spatula clypeata*) have been found in the Norfolk Forest-bed. In the *Fuligulinæ*, the type genus *Fuligula* (Pochard) is recorded from the Upper Pliocene of the Val d'Arno, in Italy, and *Nyroca* (White-eyed duck), from the Pleistocene of Queensland; while in the *Merginæ*, it is probable that *Mergus* (Merganser) was represented in the Pliocene Siwaliks of India. The extinct *Chenornis*, of the Italian Miocene, also belongs to this family, although its precise position is uncertain.

Suborder 13. Odontopteryges.—The *Odontopterygidæ*, represented by *Odontopteryx*, of the London Clay, appear to indicate a distinct subordinal group, which may be provisionally placed here. In this singular bird the alveolar margins of both jaws are furnished with tooth-like serrations (fig. 1121) which differ from true teeth in being actually parts of the osseous substance of the jaw itself, and thereby agree with those found in the Chelonian genera *Hardella* and *Batagur*. They are of triangular or compressed conical



Fig. 1121.—Skull of *Odontopteryx toliapicus*, restored; from the London Clay. (After Owen.)

form, and of two sizes. Upon the whole, *Odontopteryx* would appear to be most nearly allied to the *Anatidæ*, but the serration of its jaws is an entirely unique character, unknown in any existing type.

Suborder 14. Palamedeæ.—Of this group, comprehending only the American Screamers (*Chauna*, &c.), no fossil representatives are known.

Suborder 15. Odontoglossæ.—The only family of this group is the *Phœnicopteridæ*, or Flamingos, which are exceedingly long-limbed waders, distinguished by a peculiar downward bend of the beak, and presenting characters connecting them on the one hand with the Anseres, and on the other with the Herodiones. The existing genus *Phœnicopterus* is found in the Allier Miocene; while in the same beds, as well as in the equivalent deposits of the Mayence basin, and also in the somewhat higher strata of Steinheim, in Bavaria, occurs the peculiar genus *Palælodus*, which, while apparently allied to *Phœnicopterus*, presents some affinity to

the Limicolæ, and also shows one osteological feature now only occurring among the *Pygopodes* in *Podiceps* (Grebes) and *Colymbus* (Divers). *Elornis*, from the Lower Miocene of Ronzon, appears to be also allied to the Flamingos; while *Agnopterus*, from the Upper Eocene of Montmartre, may perhaps be also included in the present group.

Suborder 16. Herodiones.—This suborder includes the *Plataleidæ*, or Spoonbills and Ibises; the *Ciconiidæ*, or Storks; and the *Ardeidæ*, or Herons; all of which are waders. The *Plataleidæ* are represented in past epochs by an extinct species of *Ibis* (*I. pagana*), from the Allier and Steinheim Miocene; while the existing Asiatic Black-headed Ibis (*I. melanocephala*) has left its remains (fig. 1108, p. 1217) in the Pleistocene cave-deposits of southern India. Another existing species of this genus occurs in the cave-deposits of Brazil. In the *Ciconiidæ*, an extinct species of the African and Oriental genus *Leptoptilus* (*Argala*), which includes the giant Adjutant Stork of India, is found in the Pliocene Siwaliks of the latter country, and another in the Middle Miocene of Bavaria; while an undetermined Ciconioid, from the Pikermi beds of Attica, may possibly belong to the same genus. Part of a metatarsus, from the Tertiary of Argentina, indicates a bird double the size of the Pampean Stork, and has been made the type of the genus *Palæociconia*. The Indian Siwaliks have also yielded remains of another giant Stork, of which the genus has not yet been determined. In the Pleistocene of Queensland there occurs an extinct species of *Xenorhynchus*. In the *Ardeidæ* the type genus *Ardea* (Heron) is represented in the Bavarian Miocene by a species (*A. similis*) apparently closely allied to, but rather stouter than, the common Heron (*A. cinerea*); and remains of the same genus also occur in the Miocene of Allier and Gers. The Night-Herons (*Nycticorax*) are known by an extinct species in the Pleistocene deposits of the Island of Rodriguez. Finally, certain remains from the London Clay may possibly indicate that this family dates from that epoch.

Suborder 17. Steganopodes.—In the Steganopodes are included a number of web-footed Birds, such as the Darters (*Plotidæ*), Cormorants (*Phalacrocoracidæ*), Albatrosses and Frigate-Birds (*Fregatidæ*), and the Pelicans (*Pelicanidæ*), some of which are regarded as more or less closely allied to the Gaviæ, while it is suggested that there may also be a connection between this group and the Accipitres. The *Plotidæ* are only known in a fossil state by a species of the one genus *Plotus*, from the Pleistocene of Queensland. In the *Phalacrocoracidæ* we find the type genus *Phalacrocorax* (*Graculus* or *Cormoranus*) in the Eocene of Montmartre, the Allier Miocene, the Pliocene of the United States, and prob-

ably also in the Indian Siwaliks; remains of the existing Cormorant (*P. carbo*) being found in the Norfolk Forest-bed. *Sula* (Gannet) occurs in the Miocene beds of Colorado and of Ronzon (Puy-en-Velay); while *Pelagornis*, of the Allier Miocene, is provisionally placed in this family. In the *Fregatidæ* remains of a *Diomedia*, apparently closely allied to the Albatrosses of the Southern seas, have been described from beds at the top of the Suffolk Crag; while it is considered probable that *Argillornis*, of the London Clay, indicates the existence of this family in the Lower Eocene. In the *Pelecanidæ* remains of true Pelicans (*Pelecanus*) occur in the Miocene of Allier and Bavaria, as well as in the Indian Siwaliks.

Suborder 18. Accipitres.—The Accipitres, or Diurnal Birds of Prey, are characterised by their curved beak (fig. 1122, B), the absence of a circle of feathers round the eye, and the powerful talons of the foot (fig. 1122, A), as well as by many osteological features, and especially the nearly straight line formed by the three

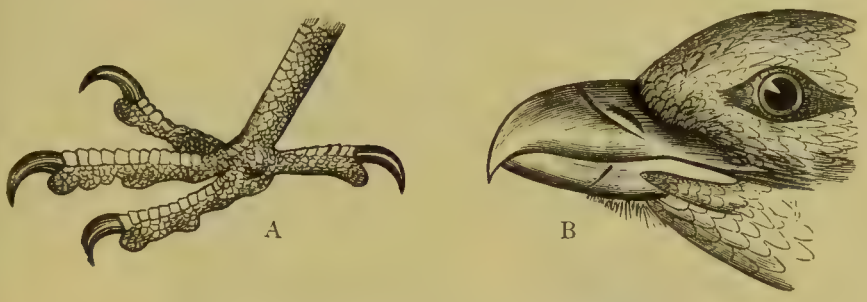


Fig. 1122.—A, Foot of the Peregrine Falcon; B, Head of Buzzard. Reduced.

terminal trochleæ of the tarso-metatarsus (fig. 1123), and the absence of a bony bridge over the extensor tendons at the distal extremity of the tibia. The probability of this group being related to the Steganopodes has been already noticed. The *Cathartidæ*, or American Vultures, are represented by existing species of *Cathartes* and *Gyparchus* in the Pleistocene of the Brazilian caves. It has also been considered that this group is represented in Europe by *Lithornis vulturinus*, of the London Clay; an opinion which, if confirmed, will be of considerable interest from a distributional point of view. The peculiar *Serpentariidæ*, or Secretary Vultures, of Africa, are known by a species of the one existing genus *Serpentarius* from the Allier Miocene. The *Falconidæ* include all the remaining genera, which are grouped in several subfamilies. Of these the *Vulturinæ*, or true Vultures, are represented in the Pleistocene breccia of Sardinia by remains of the type genus *Vultur;* while those of the existing Afro-Indian *Neophron percnopterus* are

recorded from the equivalent cave-deposits of southern India. In the other groups we have evidence of a species of either *Milvus* or *Circus* (fig. 1123) from the last-named deposits, the figure being given in order to show the form of the distal end of the tarso-metatarsus so characteristic of this suborder. *Milvus* is recorded from the Allier Miocene; and *Falco* from the Montmartre Eocene. Species referred to *Aquila* are mentioned both from the Miocene of Allier and Gers, and the Sardinian Pleistocene; while *Haliaëtus* is recorded from Gers. Of extinct genera *Palæohierax*, from the Allier Miocene, is regarded as being allied to *Aquila;* while *Palæocircus*, of the Montmartre Eocene, is described as showing affinity to the Buzzards (*Buteo*), and the Osprey (*Pandion*); *Teracus*, from the Ronzon Miocene, being an imperfectly known form. The largest known member of this suborder is *Harpagornis*, from the Pleistocene of New Zealand, which was apparently allied to *Circus*. Finally, several existing species of *Falconidæ* are recorded from the Pleistocene of the Brazilian caves.

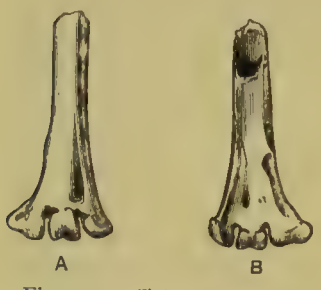


Fig. 1123.—(?) *Milvus* or *Circus*, sp. The distal half of the left tarso-metatarsus, from the anterior (A) and posterior (B) aspects; from the Pleistocene of Madras

Suborder 19. Striges.—The Striges, or Owls, were formerly

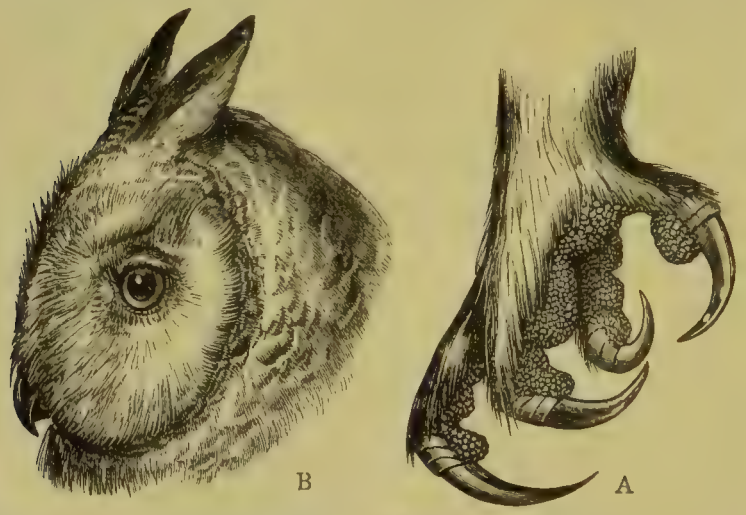


Fig. 1124.—A, Foot of the Long-eared Owl (*Otus vulgaris*); B, Head of the same. Reduced.

grouped with the Accipitres, but are now regarded as being probably more nearly allied to the Parrots. Comparatively few fossil forms are known; but in the *Asionidæ*, or Eagle-Owls, we have the

great Eagle-Owl (*Bubo ignavus*) in the Norfolk Forest-bed, and the existing Indian *B. coromandus* in the Pleistocene of Madras; while this genus is also recorded from the Allier Miocene, and is represented in the Eocene of the United States by *B. leptosteus*, which was about two-thirds the size of the existing *B. virginianus* now inhabiting the same regions. The existing Ceylon Fish-Owl (*Cetupa*[1] *ceylonensis*) occurs in the Pleistocene of Madras, and the great European Snowy Owl (*Nyctea scandiaca*) in that of Westphalia. In the *Strigidæ*, or true Owls, remains of an extinct species of *Carine* have been described from the Pleistocene of the Island of Rodriguez; while bones from the Miocene of Allier and Gers have been referred to *Strix*.

Suborder 20. Psittaci.—The Parrots, Cockatoos, and their allies, which constitute this suborder, are now confined to the warmer regions of the globe, and are remarkable for the presence of a hinge-joint at the base of the strongly-curved cranial portion of the beak, whereby the upper jaw can be moved upon the cranium proper, as is shown in fig. 1125, A. All the genera are of scansorial



Fig. 1125.—Right lateral aspect of the skull (A) and of the left pes (B) of *Psittacus erythacus*. Reduced. *a*, First (hallux); *b*, Second; *c*, Third; *d*, Fourth digit. (After Blanchard.)

habits, and the foot has a hallux (fig. 1125, B). In the *Psittacidæ*, or true Parrots, remains from the Allier Miocene have been referred to the typical African genus *Psittacus*, but that term must be used in a wider sense than the one in which it is employed by the students of recent Ornithology. *Lophopsittacus* is an extinct genus from the Pleistocene of Rodriguez. Remains of the genus *Nestor*, peculiar to New Zealand, occur in the deposits of that country which yield *Dinornis*, and probably belong to existing species. The American Macaws are represented by species of *Ara* in the Brazilian cave-deposits. In the *Palæornithidæ*, which includes the Lories and Parakeets, an extinct species of the existing African and Oriental genus *Palæornis* occurs in the Pleistocene of Rodriguez, which has also yielded the extinct *Necropsittacus*. The *Stringopidæ* of New

[1] Amended from *Ketupa*.

Zealand, and the *Cacatuidæ* (Cockatoos) of Australia, have not yet been recorded in a fossil state.

Suborder 21. Picariæ.—The *Picariæ* are a somewhat heterogeneous group of Birds, of which it will be unnecessary to mention all the families, since only a few are definitely in a fossil condition. To the African *Musophagidæ*, or Plaintain-cutters, it is thought the extinct *Necrornis*, from the Miocene of Gers, may possibly belong. The remarkable *Leptosomatidæ*, of Madagascar, which connect the *Coraciidæ* with the *Cuculidæ*, are represented by a species of the type genus *Leptosoma* in the Allier Miocene. The latter deposits have also yielded a species of *Trogon*, the type of the family *Trogonidæ*. *Limnatornis*, of the same beds, is referred to the *Upupidæ*, or Hoopoes; while it is considered that the Upper Eocene *Cryptornis* may belong to the *Bucerotidæ*, or Hornbills, of the Ethiopian and Oriental regions. The *Alcedinidæ*, or King-fishers, are represented in the London Clay by *Halcyornis;* while in the *Picidæ* (Woodpeckers) we have the existing genus *Picus* in the Middle Miocene of Isère and the Lower Miocene of Allier, and the extinct *Uintornis* in the Eocene of Wyoming. Finally, the *Cypselidæ*, or Swifts, are known to have existed since the Allier Miocene, where we find a species of the type genus *Cypselus* closely allied to existing forms.

Suborder 22. Passeres.—Of the Passeres, the last and most highly organised group of the class, an enormous number of living genera and species are known; but from the comparatively small size of the majority of species, and the difficulty of distinguishing even genera by fragmentary bones, scarcely anything is known of their palæontological history. To the *Alaudidæ* (Larks) has been provisionally referred *Protornis*, from the Lower Eocene of Glarus in Switzerland; and *Alauda* is recorded from the Upper Pliocene of Italy. In the *Corvidæ* (Crows) the type genus *Corvus* has been described from the Allier Miocene. In the Pleistocene of Rodriguez the extinct *Necropsar* is a Starling (*Sturnidæ*) closely allied to the pied and crested *Fregilopus* of Reunion, which also appears to have recently become extinct. Among the *Fringillidæ* (Finches) *Loxia* and *Passer* are provisionally recorded from the Allier Miocene; and to this family may perhaps be referred the extinct genus *Palæospiza*, from the Upper Eocene of Colorado. Finally, we have a representative of the *Laniidæ*, or Shrikes, in a species of *Lanius* from the Allier Miocene; while the *Sittidæ* (Nuthatches) date their existence at least from the fossil *Sitta* of the Montmartre Eocene, and are also represented by a species in the Upper Pliocene of Italy. Lastly, the cave-deposits of Brazil have yielded remains of several existing forms of Passerines, among which it will suffice to mention a species of Swallow (*Hirundo*).

LITERATURE OF AVES.

1. DAMES (W. B.)—"Ueber *Archæopteryx*." 'Pal. Abhandl.,' vol. ii., art. 3 (1884).
2. DAVIES (W.)—"On some Fossil Bird-Remains from the Siwalik Hills." 'Geological Magazine,' dec. ii., vol. vii. (1880).
3. EDWARDS (A. MILNE-).—"Récherches Anatomiques et Paléontologiques pour servir à l'histoire des Oiseaux fossiles de la France." Paris (1867-77).
4. GÜNTHER (A.), and NEWTON (E.)—"The Extinct Birds of Rodriguez." 'Transit of Venus Expedition.'
5. HAAST (J. VON).—"On *Harpagornis*, an Extinct Genus of gigantic Raptorial Birds of New Zealand." 'Trans. New Zealand Institute,' 1874.
6. —— "On *Megalapteryx Hectori*, a new Gigantic Species of Apterygian Bird." 'Trans. Zool. Soc.,' vol. xii. (1886).
7. HUXLEY (T. H.)—"On the Classification of Birds." 'Proc. Zool. Soc.' 1867.
8. LEMOINE (V.)—"Récherches sur les Oiseaux Fossiles des Terrains Tertiaires des Environs de Reims," parts 1 and 2. Rheims (1878-81).
9. LYDEKKER (R.)—"Siwalik Birds." 'Palæontologia Indica' (Mem. 'Geol. Surv. Ind.'), ser. 10, vol. iii., part 4 (1884).
10. MARSH (O. C.)—"Odontornithes: A Monograph of the Extinct Toothed Birds of North America." Washington (1880).
11. —— "Discovery of a Fossil Bird in the Jurassic of Wyoming." 'American Journal of Science,' ser. 3, vol. xxi. (1881).
12. NEWTON (A.)—"Ornithology." 'Encyclopædia Britannica,' 9th ed.
13. —— and (E.)—"Osteology of the Solitaire or Didine Bird of the Island of Rodriguez." 'Phil. Trans.' 1869.
14. —— (E.), and CLARK (J. W.)—"On the Osteology of the Solitaire (*Pezophaps solitaria*, Gmel)." 'Transit of Venus Expedition.'
15. —— (A.) and PARKER (W. K.)—"Birds." 'Encyclopædia Britannica,' 9th ed. (1875).
16. OWEN (R.)—"*Archæopteryx macrura*." 'Phil. Trans.' 1863.
17. —— "Memoir on the Dodo." 1866.
18. —— "Memoir on the Extinct Wingless Birds of New Zealand." London (1878).
19. —— "On *Argillornis longipennis*, Owen, a large Bird of Flight, from the Eocene Clay of Sheppey." 'Quart. Journ. Geol. Soc.,' vol. xxxvi. (1880).
20. —— "On the Skull of a Dentigerous Bird from the London Clay of Sheppey." 'Quart. Journ. Geol. Soc.,' vol. xxix. (1873).
21. —— "On Dinornis." 'Trans. Zool. Soc.' 1839-85.
22. —— "Osteology of the Dodo." 'Trans. Zool. Soc.' 1867.
23. PORTIS (A.)—"Contribuzioni alla Ornitologia Italiana," part 2. 'Mem. Ac. R. Torino,' ser. 2, vol. xxxviii. (1887).
24. SEELEY (H. G.)—"On the British Fossil Cretaceous Birds." 'Quart. Journ. Geol. Soc.,' vol. xxxii. (1876).
25. STRICKLAND (H. E.) and MELVILLE (A. G.)—"The Dodo and its Kindred." London (1848).

26. Vis (C. W. de).—"A Glimpse of the Post-tertiary Avifauna of Queensland." 'Proc. Linn. Soc. N. South Wales,' vol. iii. (1888).
27. Vogt (C.)—"L' *Archæopteryx macrura*—Un Intermédiare entre les Oiseaux et les Reptiles." 'Rev. Sci. France et l'Etranger,' vol. ix. (1879). Translated in the 'Ibis' for 1880.
28. Winge (O.)—"Fugle fra Knoglehaler i Brasilien" (Birds from the Brazilian Bone-Caves). 'Museo Lundii' (1887).
29. Woodward (H.)—"On Flightless Birds." 'Proc. Geologists' Association,' vol. ix. (1886).

CHAPTER LVIII.

CLASS MAMMALIA.

GENERAL STRUCTURE.

The Mammalia, or highest class of the Vertebrata, are characterised by having some part of the integument provided with hairs at some period of life, and by the young being nourished for a longer or shorter time by the milk, or special secretion of the mammary glands. As characters available in the case of fossils, it may be observed that the cranium articulates with the atlas vertebra by two occipital condyles, mainly formed by the exoccipitals; while each ramus of the mandible consists of only a single piece, which proximally articulates directly with the squamosal element of the cranium without the intervention of a quadrate; and there is no movable joint between the proximal and distal rows of the tarsus. Like the Sauropsida, Mammals possess during development an amnion and allantois, and are totally devoid of gills. They differ from Reptiles and agree with Birds in having a four-chambered heart, warm blood, and a complete double circulation. They are peculiar in that the red corpuscles of the blood are not nucleated and usually circular; in the lungs being freely suspended in the thoracic cavity, which is separated from the abdomen by a muscular partition termed the *diaphragm;* in the presence of only the left aortic arch; and in the perfection of the transverse commissure (corpus callosum) connecting the two cerebral hemispheres. Feathers, moreover, are never present, and there is no *syrinx* or lower vocal organ, although a complete *larynx* is always developed in the upper portion of the *trachea*, or respiratory tube.

It will be unnecessary in this work to make any further mention of the soft parts, but a few remarks must be made concerning the tegumentary and dental systems, and the endoskeleton; although the student must refer to other works for fuller information on these subjects. With regard to the tegumentary system, it will suffice to

observe that imbricated horny scales occur in the epidermis only in the family *Manidæ* among the Edentata; and flat horny shields, with their edges in apposition, in the tails of the Beaver, Rats, and certain Insectivores and Marsupials. The Armadillos and Glyptodonts develop, however, a series of bony scutes articulating with one another in the true dermis, which are covered by horny epidermal shields; the whole structure being thus precisely comparable to that obtaining in the Crocodilia. Smaller separate bony scutes also occur in the dermis of *Mylodon*. The horns of the Ruminants and Rhinoceroses are entirely epidermal structures; the former being hollow sheaths enveloping bony cores, while the latter are solid throughout.

The dental system, as being of extreme importance for the determination of the extinct forms, must be noticed somewhat more fully. Calcified teeth are developed in the great majority of Mammals, but in the true Whales they occur only in the embryo, in *Ornithorhynchus* they disappear in the adult, while in *Echidna*, *Manis*, and *Myrmecophaga*, no traces of them have as yet been detected. In the adult of *Ornithorhynchus* and *Rhytina* the function of teeth is discharged by horny plates, or *cornules* on the palate. In all other forms, however, true teeth, which are developed only in the premaxilla, maxilla, and dentary bones, are present; and are usually composed of the three elements, dentine, enamel, and cement, although occasionally, as in the existing Edentates, the enamel is absent. The dentine, or ivory, forms the chief constituent of most teeth. This is coated, either completely or partially, in the majority of cases by a thin investing layer of the hard flint-like enamel, which is readily distinguished from the dentine by its bluish-white and translucent appearance, while the outermost coat of cement, when present, is of a dull opaque white, or buff, colour. The cement is frequently found only as a thin coating at the roots of the teeth; but it is very largely developed in the crowns of the hinder teeth of many Ungulates. In the teeth of the great majority of Mammals (as in fig. 1126) the crown, or exposed portion, is sharply defined by a construction known as the *neck* from the root, or embedded portion; but in those teeth to be immediately noticed, which grow continuously, there is no such distinction between the crown and the root. In no Mammals are the teeth anchylosed to the bones of the jaw;[1] and they are invariably implanted in distinct alveoli, or sockets, which are, however, very imperfect in certain Cetacea. In all young animals, while the teeth are still growing, the inferior extremity of the root, or roots, is widely open; but in the majority of instances this aperture becomes completely closed in the adult (fig. 1126). In certain

[1] Except, perhaps, the incisors of the Shrews.

cases, however, as in the anterior cutting-teeth of the Rodents and the tusks of the Elephant, the root remains permanently open below, and the tooth consequently continues to grow throughout the life of the animal. In such circumstances the teeth are said to have persistent pulps. The anterior teeth (fig. 1126, *c*, *i*), with some rare exceptions, are of simple structure and have but a single root; but the hinder ones (*ibid.*, *pm*, *m*) very generally have more or less complex crowns, which may be supported by from two to four roots; such division of the roots being unknown outside the Mammalian class. In many forms the summits or sides of the crowns of the hinder teeth may be interpenetrated by deep re-entering folds of enamel, which may be filled up with cement; these folds being espe-

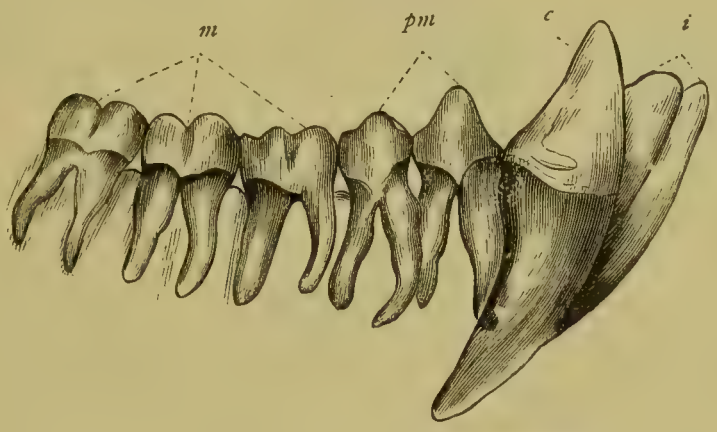


Fig. 1126.—Teeth of the right side of the lower jaw of the Chimpanzee. *i*, Incisors; *c*, Canine; *pm*, Premolars; *m*, True molars. (After Owen.)

cially developed in many Rodents and Ungulates. From this structure it will naturally result that when a horizontal section of the crown of such a tooth is made by the wearing of the upper against the lower series, an extremely complex pattern will appear, as will be seen in the figures of the cheek-teeth of the above-mentioned groups which are given below. Much more rarely, as in the Horse, there may be an infolding of the enamel in the summits of the crowns of the anterior teeth.

With the exception of the above-mentioned edentulous forms, in all existing Mammals one definite set of teeth, which is almost always constant in number, is developed, and this set when it appears usually persists throughout the remaining portion of the life of its owner. In a large number of species this is the only set ever developed; and such species, or groups of species, are consequently said to be *Monophyodont*. In the greater majority of Mammals, however, the development of occasionally only one, but usually of the greater number of the anterior teeth of this permanent set is

retarded, and their function filled for a time by an earlier series of so-called milk-teeth; such Mammals being accordingly termed *Diphyodont*. As development proceeds the permanent teeth in such Mammals come up beneath the milk-teeth, and thus replace them in a vertical direction; but there are instances where certain of these milk-teeth have no such permanent successors, while in other cases the anterior teeth which come into use with the permanent dentition have no milk predecessors. Those Mammals with a Mono-

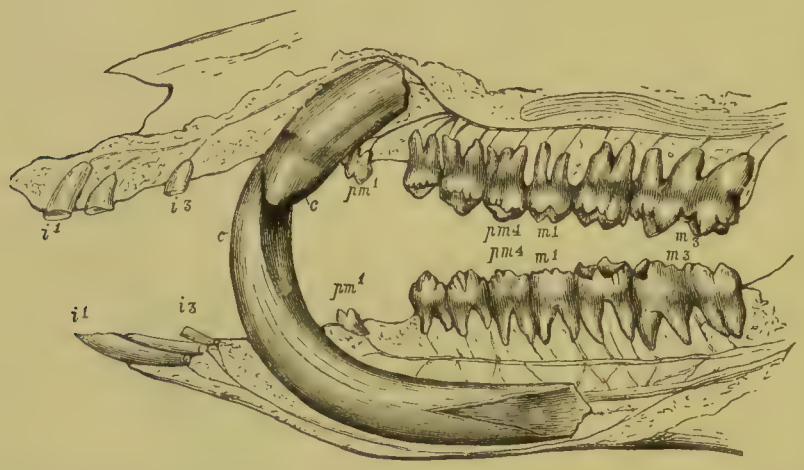


Fig. 1127.—Outer lateral aspect of the left dentition of the Pig (*Sus scrofa*), with the outer lamina of bone removed, in order to exhibit the roots of the teeth. *i*, Incisors; *c*, Canine; *pm*, Premolars; *m*, True molars.

phyodont dentition present the least specialised development, since the milk-series appears from the latest researches to be an addition grafted on to the permanent one; and there is accordingly no homology between this definite single replacement and the irregular continuous change which takes place in many Reptiles. In some Mammals, like the Dolphins (*Delphinidæ*), all the teeth are so much alike that they cannot be divided into groups, and the dentition is then described as *Homœodont;* but in the majority the permanent teeth, either from their position or their mode of succession, can be separated into four distinct groups (as in figs. 1126, 1127), and the dentition is then termed *Heterodont*. In Eutherian Diphyodont Mammals the total number of teeth of the permanent series does not normally exceed 44; and in forms like *Sus* (fig. 1127), or the extinct *Anoplotherium*, where this full complement is present, the first three upper teeth (*i* 1-*i* 3) on either side, which are situated in the premaxillæ, are termed *incisors;* the last three (*m* 1-*m* 3), which are distinguished by having no milk-predecessors, *true molars;* the four submolariform teeth (*pm* 1-*pm* 4) in advance of the latter, of which the last three have such deciduous predecessors, *premolars;* and

the single subconical tooth (*c*) situated between the premolars and the incisors the *canine;* the latter tooth being the first of those borne by the maxilla. The same terms are applied to the corresponding lower teeth, although it will be unnecessary here to indicate how such serial correspondence is worked out. For the sake of brevity such a dentition may be expressed by the numerical formula — $I.\ \frac{3—3}{3—3}$; $C.\ \frac{1—1}{1—1}$; $Pm.\ \frac{4—4}{4—4}$; $M.\ \frac{3—3}{3—3} = 44$; but since the teeth of opposite sides of the jaws always correspond, such a formula may be further simplified into—

$$I.\ \frac{3}{3};\ C.\ \frac{1}{1};\ Pm.\ \frac{4}{4};\ M.\ \frac{3}{3} = 22 \times 2 = 44.$$

The individual teeth of each group are enumerated from before backwards, and by such a formula as the following—viz.,

$$\frac{I.\ 1,\ I.\ 2,\ I.\ 3,\ C.,\ Pm.\ 1,\ Pm.\ 2,\ Pm.\ 3,\ Pm.\ 4,\ M.\ 1,\ M.\ 2,\ M.\ 3,}{I.\ 1,\ I.\ 2,\ I.\ 3,\ C.,\ Pm.\ 1,\ Pm.\ 2,\ Pm.\ 3,\ Pm.\ 4,\ M.\ 1,\ M.\ 2,\ M.\ 3,}$$

—each individual tooth can be specially noted. Thus, for example, *pm.* 1 will indicate the first upper premolar, and *m.* 3 the third, or last, lower true molar. It will frequently, moreover, be convenient to speak of the incisors and the canine collectively as the *cutting-*, and of the premolars and true molars as the *cheek-teeth.* It is very generally the case that when the true molars are reduced to less than three it is the hinder tooth, or teeth, that disappear; in the premolars it is, however, frequently the anterior teeth that are wanting, although this is by no means invariably the case, and there are instances known where the second and fourth disappear, while the first and third remain. In the figure of the lower dentition of the Chimpanzee given on page 1247, the two premolars are usually reckoned as *pm.* 3 and *pm.* 4, but it is not certain that such is really the case. Again, it has been suggested that the two incisors found in that species, in common with other Primates, may be the first and third of the typical Eutherian series of three, although other authorities regard them as the second and third. It may also be observed that in some groups, as the Carnivora, the specialised forms tend to lose the molars and retain the full number of anterior teeth; while in others, like the Ungulates, the reverse condition obtains.

The milk-dentition may be expressed by a similar formula with the prefix of the letter *M.* to the symbols. The typical milk-series will thus be written as $M.i.\ \frac{3}{3}$, $M.\ c.\frac{1}{1}$, $M.m.\ \frac{3}{3}$; the three milk-molars corresponding to the last three premolars of the permanent series. In a few Ungulates, however, such as *Tapirus*, and sometimes *Rhinoceros* and *Palæotherium*, four milk-molars are developed.

Among the existing Metatheria the number of true molars is generally $\frac{4}{4}$, while the premolars are very frequently reduced in number, and there may be five upper incisors. In one existing, and several Mesozoic members of that subclass, the number of true molars exceeds four; but, with the possible exception of some of these extinct types, there is no known instance of a heterodont Mammal normally having more than four premolars; and there is never more than a single canine tooth on either side of each jaw.

Since in Ungulates it is sometimes difficult to distinguish molars from premolars, it may be well to mention how the division between the two series can always be determined. Since the first tooth of the true molar series always comes into use before the last milk-molar is shed, it is obvious that in the adult the first true molar will always be more worn than the last premolar. Thus, in the three teeth of *Hipparion* represented in fig. 1233, the tooth on the left side of the figure being more worn than the one in the middle is thereby shown to be the first of the true molar series; the other two being consequently premolars.

The different types of cheek-teeth will be mentioned under the head of the various orders and families, but a few general observations may be recorded here. Professor Osborn considers that the primitive Mammals had simple conical teeth with undivided fangs, and that the crowns of the teeth of the upper and lower jaws mutually interlocked. Teeth nearly approaching to this type occur in the Triassic *Dromatherium* (fig. 1140), while those of the Dolphins are looked upon as a reversion to this type. Another simple type, according to the views of the same author, is that found in *Triconodon* and *Priacodon* (fig. 1147), where the upper and lower teeth alike consist of three cusps in a line; the upper teeth biting on the outer side of the lower. A third common, and apparently very generalised, type of tooth is that known as the *tritubercular*. This consists in the upper teeth of one inner and two outer cusps, arranged in a triangle; while in the lower jaw the reverse arrangement obtains, so that there is one cusp on the outer and two cusps on the inner side of the crown. An example of this type of structure in its simplest form occurs in the Mesozoic genus *Spalacotherium*. Modifications of this type occur in the lower teeth of many Marsupials (*e.g.*, fig. 1145), and also in the lower carnassial teeth of the Carnivora, of which mention is made in the sequel. The tritubercular type of tooth is regarded by the American Palæontologists as one which has given rise to a large number of the more complex modifications; and it is extremely common among the generalised Mammals of the Lower Eocene.

In adult Mammals, as in the Sauropsida, the whole of the primitive cartilaginous cranium is replaced by extensive ossifications, except in the ethmoidal region; and these bones, with the exception of those of the mandible, hyoid arch, and internal auditory apparatus, are similarly articulated together at their edges by suture. As age goes on there is generally a tendency to the obliteration of these sutures, this being most marked in *Manis*. In all cases the parasphenoid has ceased to exist as a distinct ossification. It has already been observed that the hinder part of the cranium articulates with the first, or atlas, vertebra by two exoccipital condyles, and also that each of the two rami of the mandible is composed of a single bone articulating at its proximal or hinder extremity with the squamosal of the cranium. Owing to the complete incorporation of the squamosal and parietal in the walls of the brain-case there is (as in the Birds) no superior temporal arcade; but an inferior, or zygomatic, arcade is nearly always present; and, as in Crocodiles (although not in Birds), forms the lower border of the orbit. This inferior temporal arcade, or arch, differs, however, from that of most Sauropsida in that its jugal element articulates directly with the squamosal, in which respect it accords with that of the Dicynodont Reptiles, and should be known as a squamoso-maxillary arcade. According to the view of Professor Huxley, the Sauropsidan quadrate has been taken up into the inner ear to form the malleus. More recently, however, other writers have taken a different view, and, according to Dr Baur, the representative of the quadrate is to be found in the zygomatic process of the squamosal, with which the jugal articulates; the quadratojugal being also represented at the junction of these two bones. Dr Gadow, however, disputes this view, and finds the representative of the quadrate in the tympanic ring, this determination according with the view here taken as to the homology of the zygomatic arcade, which appears to have no quadratojugal element.

Again, when, as in the Primates and many Ungulates, the orbit is bounded posteriorly by a bony postorbital bar, the ascending process of the jugal articulates directly with the frontal, without the intervention of the postorbital or postfrontal, which forms such a conspicuous feature in the Reptilian skull.

In all cases the premaxillæ, maxillæ, and palatines develop inferior palatal plates which meet in the median line below the nasal passage, and thus completely separate the latter from the cavity of the mouth. Except, however, in the Anteaters (*Myrmecophaga*), in one genus of Armadillo (*Tatusia*), in certain Cetaceans, and in one species of *Hyænodon*, this flooring of the nasal passage does not extend backwards to include the pterygoids, as it does in modern Crocodilians. The palatines are always placed behind the maxillæ.

Finally, the sclerotic of the eyeball never develops a ring of bony plates like that so frequently found in the Sauropsida.

A characteristic feature of the larger bones of Mammals, although one by no means peculiar to the class, consists in their ossifying from several distinct centres. In the case of the long bones the shaft is formed by one centre of ossification, while two distinct elements termed epiphyses form the extremities; in the adult the whole of these being welded together into a solid mass. The long bones are also tubular, and their vacuity is filled with the fatty marrow.

The vertebræ always have well-developed articular processes on their arches; the ends of the centra are generally flattened, but in the cervical region of certain Ungulata they may be opisthocœlous. Terminal epiphyses, so generally wanting in the Sauropsida, are nearly always present. The number of vertebræ varies greatly, owing to the great difference in the length of the tail in different species; but in the majority of Mammals the number of precaudal vertebræ does not vary very far from thirty, although in *Hyrax* and *Cholœpus* their number reaches forty. In spite of the great difference in the length of the neck in different Mammals, the number of cervical vertebræ in existing forms is, with three normal exceptions, seven. These exceptions are *Manatus australis* and *Cholœpus Hoffmanni*, in which the number is reduced to six, and *Bradypus tridactylus*, in which it is increased to nine. According, however, to Professor W. K. Parker there may occasionally be eight cervicals in the Pangolin (*Manis*). The first, or atlas, vertebra always has two articular cups for the occipital condyles; and, except in certain Cetacea, the second, or axis, has a well-defined odontoid process. Usually the cervical vertebræ are quite free; but they are anchylosed together in some of the Cetacea, and in the Armadillos. The dorsal vertebræ are usually well defined from the lumbar, although this is not invariably the case; and the number of dorso-lumbars in any one given group is usually very constant, and among the Ungulata affords assistance in classification. A distinct sacral region is present in all Mammals except the Cetacea, where the iliac bones are absent. The number of caudal vertebræ varies from three (certain Primates) to forty-six (*Manis*). Chevron-bones are present in the caudal region of many long-tailed forms. The sternum is always present, although varying greatly in form. It usually consists of a *presternum* (fig. 1128, *p*) and of a posterior *xiphisternum* (*x*), between which are a varying number of segments (*m*) constituting the *mesosternum*. The segments of the mesosternum (fig. 1128, A) may be anchylosed together; and in the *Balænidæ*, among the Cetacea, only the presternum is present. The connection of the ribs with the sternum is generally by cartilage; but in the Armadillos the costal cartilages ossify, and are then

known as *sternal ribs*. In the anterior dorsal region the capitular head of the ribs articulates with the vertebræ in a pit at the junction of two centra, while the tubercular head joins the transverse process of the second of these two vertebræ; but in the posterior dorsal region the two heads generally coalesce. Dr Baur regards the intervertebral articulation of the capitula in the anterior region as a direct survival of the intercentral attachment of the ribs of primitive forms allied to Theriodont Anomondontia, which has been totally lost among other Reptiles; and the mode of costal articulation is

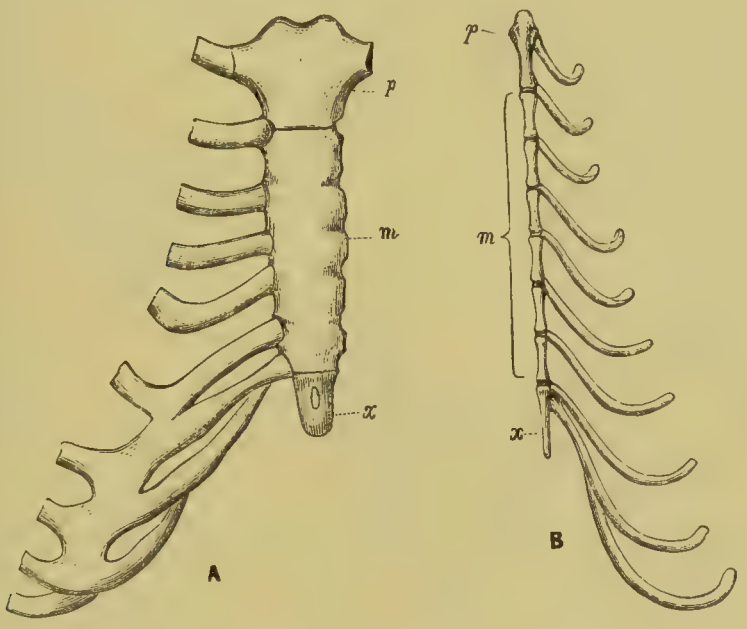


Fig. 1128.—A, Sternum and right costal cartilages of Man; B, Sternum and left costal cartilages of Dog. *p*, Presternum; *m*, Mesosternum; *x*, Xiphisternum.

undoubtedly very near to that of those Anomodonts which have lost the intercentra. Uncinate processes are never present on the ribs.

In all Mammals the pectoral limb is well developed. The pectoral girdle is, however, usually simpler than in lower forms; the coracoid persisting as a distinct bone only in the Monotremata, where, however, it anchyloses to the scapula. An interclavicle is present only in the last-named order; where it articulates with the clavicles after the Reptilian manner. In the Eutheria the clavicles only retain their complete development in those groups, such as the Insectivora, many Rodentia, the Chiroptera, and the Primates, which use the pectoral limb for flight, burrowing, or prehension. The humerus frequently has an entepicondylar foramen, like that of the Anomodont Reptiles. The radius and ulna retain their original

pre- and postaxial position in the Cetacea; but in most other Mammals they are crossed at their distal ends, so that their positions become reversed, and in the "prone" or normal position of the limb the radial, or preaxial border of the hand, becomes internal. In the Primates, however, these bones admit of motion upon one another; and when the hand is "supine" (that is, with its palm directed forwards or upwards), the bones of the fore-arm occupy their original primitive position. In the majority of those Mammals whose limbs are adapted solely for walking, the ulna is more or less reduced, and the radius, especially at its proximal end, is much enlarged, so that it articulates with the whole of the anterior surface of the humerus; and thus comes in front of the ulna, instead of at its side. The carpus essentially corresponds with that of the type represented in fig. 829 (p. 907); the radiale,[1] intermedium, and ulnare being termed the scaphoid, lunar, and cuneiform; the trapezium, trapezoid, and magnum representing the 1st, 2d, and 3d carpalia, and the unciform the 4th and 5th of that series. A centrale is present in the carpus of embryos of pentedactylate forms; but in the adult it usually fuses with the scaphoid, although it remains distinct in most of the Primates. In some groups others of these elements may also coalesce, and one or more may be absent. The pisiform, or presumed representative of the seventh digit, is generally well developed; while in pentadactylate types there may be an ossification representing the prepollex. The metacarpals and digits may be five in number (Proboscidea and Primates), or may be reduced to two, or even to one functional member. Among the Ungulata, when the metacarpus is reduced to a single functional element, as in the Horse, such element is frequently termed the *cannon-bone;* in anatomy, however, this term is more usually restricted to the metapodium of those Artiodactyla which consists of the coalesced third and fourth metapodials. Except in the Cetacea there are never more than three phalangeals to each digit, but by suppression or anchylosis this number is occasionally reduced; and the first digit (pollex) has but two phalangeals. The pelvic girdle is also fully developed in all Mammals except the Cetacea and Sirenia; and in the adult the three elements coalesce to form an *innominate* bone. The pubis and ischium of the same side always unite to enclose the obturator foramen; and the two pubes meet in a ventral symphysis, which is, however, not completely united in certain Insectivora. In a large number of instances the ischia meet in a ventral symphysis,

[1] Since the preceding chapters were in type, Dr Baur has expressed his opinion that the bone termed radiale in fig. 829 is really a second centrale; and that the radiale is represented by a minute bone generally known as the radial sesamoid. The Mammalian scaphoid is accordingly also regarded as a second centrale. In the same communication, Dr Baur expresses his disbelief in the existence of remnants of a prepollex and of a seventh digit in Mammals and other Vertebrates.

which is greatly elongated in some Ungulates (fig. 1128 *bis*), but in the Primates and some other forms there is no such union. In the Monotremata and Marsupialia epipubic, or *marsupial*, bones are attached to the anterior border of the pubic symphysis (fig. 1139). The femur may have a third trochanter (fig. 1226) for the attachment of one of the gluteal muscles. The tibia and fibula are never crossed at their distal extremity, but lie in their primitive parallel position; the tibia, or preaxial bone, being internal in the usual walking position, and the fibula external. The latter bone may be more or less rudimentary, and completely anchylosed at one or both

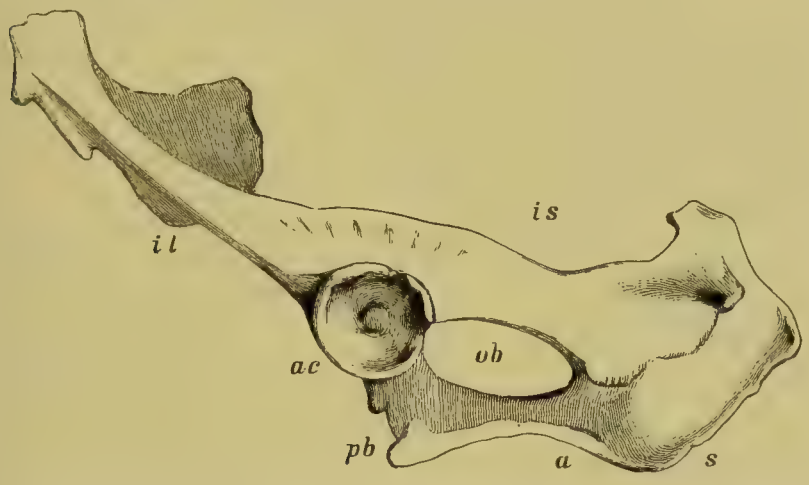


Fig. 1128 *bis*.—The left side of the pelvis of the Eland (*Oreas canna*). One-sixth natural size. *il*, Ilium; *is*, Ischium; *s*, Symphysis of do.; *a*, Epiphysis on symphysis of ischium and pubis; *pb*, Pubis; *ob*, Obturator foramen.

extremities to the tibia. The patella is present in all except some Metatheria. If the pes (fig. 1129) be compared with the typical tarsus mentioned on p. 907, it will be found that the fibulare is represented by the calcaneum, which may also contain an element corresponding to the pisiform of the manus; the astragalus has been usually regarded as the coalesced tibiale and intermedium, but is thought by Dr Baur to correspond solely to the latter; the ento-, meso-, and ectocuneiform represent the 1st, 2d, and 3d tarsalia; while the 4th and 5th tarsalia have coalesced to form the cuboids. The centrale persists as the navicular, which may unite with the cuboid.[1] Other modifications occur analogous to those in the carpus; but in no instance, as already observed, is the joint between the leg and the pes formed on the line between the proximal and distal rows of the tarsus. The metatarsals and phalan-

[1] Dr Bardeleben has pointed out to the writer that in *Cryptoprocta* there may be a second centrale, which usually coalesces with the ectocuneiform.

geals repeat the characters of the homologous bones of the manus, although they deviate in a lesser degree from a common type. In the Cetacea and Sirenia the pes is entirely absent; although the proximal portions of the pelvic limb may be detected in an aborted form in many genera.

We may now take a brief glance at the general distribution in time of the Mammalia, in the course of which we shall have to forestall some of the information given in the sequel.

If the theory of evolution be the true explanation of the order of nature we should expect to find that the earliest representatives of the class would be small forms, more or less closely related to one another, not numerous in generic types, and allied to those orders which now comprise the most generalised representatives of the class. Our knowledge of these earlier types is indeed exceedingly imperfect, but so far as it goes it appears to accord fairly well with the foregoing conditions; all the earlier forms being of small size, and apparently more or less closely allied to the existing Marsupials, and probably also to the Monotremes and perhaps the Insectivores. The earliest evidence of the occurrence of Mammals yet known is in the upper portion of the Triassic system, which forms the base of the great Mesozoic period. Of the two known genera from these deposits the larger type, termed *Dromatherium*, exhibits some curious approximations in the structure of its teeth to Reptiles and Amphibians, and it is possible that we may have in this form an ancestral type of the Prototheria. In the Lower Jurassic, immediately above the Lias, remains of small Mammals become more common, and in the Upper Jurassic they are locally abundant, although they comprise comparatively few generic types. These Jurassic Mammals are readily divisible into two groups, distinguished by the characters of their teeth. Of the first group an example of the lower jaw is shown in fig. 1141, p. 1274, where it will be seen that the teeth are very numerous, the hinder ones having several sharp cusps on the crowns. Although there has been much discussion as to the affinities of these small Mammals, it is probable that they are really Marsupials of the suborder Polyprotodontia, with a relationship to the Australian Anteater (*Myrmecobius*), which,

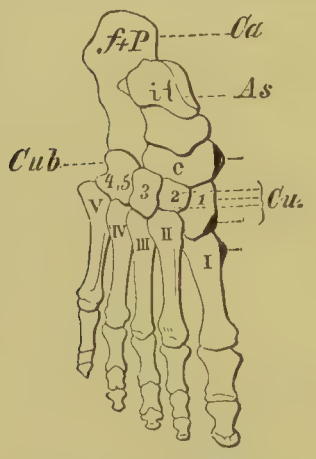


Fig. 1129.—Dorsal aspect of the right pes of Man. Reduced. *Ca*, Calcaneum (fibulare + ? pisiform); *As*, Astragalus (intermedium); *c*, Navicular (centrale); *Cu*, 1-3, Ento-, meso-, and ectocuneiform (1st, 2d, 3d tarsalia); *Cub*, Cuboid (4th, 5th tarsalia); i-v, Metatarsals. (After Wiedersheim.)

as we shall see in the sequel, is the only existing heterodont Mammal with more than four true molars. In the second group the dentition is of a very different type; the lower jaw having a single pair of curved and chisel-like incisors, separated by an interval from the cheek-teeth, which are characterised by the presence of one or more longitudinal grooves. The serial position of this group, which has been named Multituberculata, is still open to doubt, but not improbably it may indicate an extinct order of Prototheria.

Throughout the greater part of the Cretaceous period our knowledge of Mammalian life is a blank, doubtless owing to the circumstance that the greater portion of the Cretaceous beds, such as the Chalk, is of purely marine origin; but evidence has recently been obtained of the existence of a Mammalian fauna in the topmost Cretaceous of North America allied to that of the Jurassic.

With the dawn of the Tertiary period, which may be regarded as the first commencement of the present order of nature, we meet, however, with an abundant Mammalian fauna, containing representatives of nearly all the existing orders, but also including several subordinal types now totally passed away, some of which are of extreme interest to the zoologist as connecting together more or less completely groups which are now widely separated. In the Eocene we are indebted to the palæontologists of the New World for most of our knowledge of these primitive connecting links; but we can only afford space to notice very briefly some of the more interesting groups.

Of Carnivorous types there is a group of Eocene genera known as the Creodonta, remarkable, among other features, for their generalised dentition, which has resemblances to that of the Polyprotodont Marsupialia and Insectivora, and also to that of the modern Carnivora, of which these forms were probably the ancestors. We thus have indications how the Carnivora of the present day may have been gradually evolved from a Marsupial type by means of forms more or less nearly related to the Insectivora of the present epoch. In another direction the Eocene has afforded evidence of a transition from the Insectivorous type towards that of the Lemuroid Primates, and we may thus readily conceive how the higher members of the latter order may likewise trace back their origin to the same primitive stock.

At the present day no orders of Mammals appear more sharply defined from one another than the Carnivores and the Ungulates. In the Eocene, however, we meet with a group of primitive Ungulates, known as the Condylarthra, presenting such remarkable resemblances to the primitive Carnivores, that we are led to the conclusion that the Ungulates are probably another branch derived

from this same prolific stock. From this Condylarthrous suborder we have abundant evidence that the two existing suborders of the Artiodactyla and Perissodactyla, now so sharply distinguished, have both taken their origin; and perhaps the Hyracoidea may also trace their derivation from this group. Another extinct Eocene suborder of Ungulates, comprising the Coryphodons of Europe and America, and the huge and uncouth Dinocerata of the United States, tends to show a connection between the Perissodactyla and Proboscidea, which till recently were referred to distinct orders.

All living Ungulates, as we shall subsequently mention, are distinguished by the total absence of clavicles, but in the remarkable *Typotherium*, of the Pleistocene of South America, these bones were retained. In its dentition, moreover, that genus shows features now peculiar to the Rodents; and by its help, together with the evidence afforded by an Eocene group known as the Tillodonts, we can dimly see how the Rodents may have been connected with the ancestors of both the Ungulates and the Carnivores.

Having seen from these brief notices how intimate appears to have been the relationship between the chief terrestrial orders of Mammals in the Lower Eocene, we may glance at the evidence afforded by the Mammals of the Eocene as to the connection between some of the families of these orders. Among the Carnivora, no two families are better distinguished than the Dogs, or *Canidæ*, with their triangular upper molars and digitigrade feet, and the Bears, or *Ursidæ*, in which the upper molars are rhomboidal and the feet are plantigrade. In the Eocene, however, we have *Amphicyon*, with the teeth of a Dog and the limbs of a Bear; and in the later Tertiary the Bear-like *Hyænarctus*, of which the dentition retains many Dog-like features. So perfect, indeed, is the transition between Dogs and Bears, that it seems convenient to include both groups in a single family. Again, in another direction, the Dogs of the Eocene seem to pass imperceptibly into the Civets (*Viverridæ*) through *Cynodictis;* while it is almost impossible to distinguish the Civets from the Hyænas on the one hand, and the Cats (*Felidæ*) on the other. Still more remarkable is the apparent connection in the Eocene of the Civets with the Weasels (*Mustelidæ*), since these two families are widely sundered at the present day.

Turning to the Ungulates, at the present day the Artiodactylate suborder can be readily divided into four sections—viz., the Pigs, or Suina; the Camels, or Tylopoda; the Chevrotains, or Tragulina; and the Cattle and Deer, or Pecora. When, however, we go back to the early Tertiary, we find a complete transition from the Suina to the Pecora; while it is almost impossible to distinguish Deer from Chevrotains; and the early Camels exhibit signs of close

connection with the other families. Similarly, at the same period the Pigs of the Old World appear to be inseparable from the Peccaries of the New; while the Giraffes were probably as closely connected with the Antelopes on the one hand, and the Deer on the other. Again, in the Perissodactylate suborder Tapir-like forms appear to have passed into Rhinoceroses on the one hand, and into the Horses on the other.

Many other equally striking instances could be cited of the mutual connection of the Eocene Mammals with one another; but enough has been stated to show that the present sharply defined distinction of the orders and families into which we find it convenient to divide the class is, so to speak, but a feature of to-day.

In the Lower Eocene all the genera of Mammals appear to be extinct; but in the Upper division of the same period, which is frequently termed the Lower Oligocene, we meet with a few existing genera, such as *Didelphys*, *Rhinoceros*, *Viverra*, *Mustela* (Weasel), and perhaps *Canis*. In the succeeding period, or Miocene, existing genera become more common; thus in the Lower and Middle divisions of that period we meet with Otters (*Lutra*), *Rhinoceros*, Tapirs (*Tapirus*), and Gibbons (*Hylobates*). The middle division of the Miocene is, indeed, noteworthy for the appearance of Anthropoid Apes and the Proboscidea, or Elephants and Mastodons. Deer of extinct genera are abundant; but these were either devoid of antlers, or, if these appendages were present, they were small and simple. The teeth of the Ruminant Ungulates (Deer and Cattle) were, moreover, low-crowned or brachydont (fig. 1213), and the Rhinoceroses had in most cases not yet developed horns.

With the commencement of the Pliocene period the Mammalian fauna assumes a much more modern appearance. Thus we have Porcupines (*Hystrix*), Hyænas, large Tiger-like Cats (*Felis*), numerous Antelopes, Giraffes, Deer (*Cervus*), and Horse-like animals (*Hipparion*); while in India true Elephants (*Elephas*) had made their appearance. There was still, however, a large number of extinct genera. By this time many of the Deer had acquired complicated antlers; many of the Ruminants had tall-crowned or hypsodont teeth; the Rhinoceroses had horns; and the Pigs had developed large tusks in the males. In India during some portion of the Pliocene, not only Elephants, but true Horses (*Equus*), Hippopotami, Wolves, Bears (*Ursus*), and Oxen (*Bos*) had already made their appearance; but in Europe these genera are unknown before the top of the Pliocene, when we first meet with remains of a few existing species, such as the African Hippopotamus and the Striped Hyæna.

In the succeeding Pleistocene period, which may in reality be

regarded merely as the commencement of the epoch in which we are now living, the greater number of the Mammals of Europe belong to existing genera, and a considerable proportion of these to living species. The fauna of Europe in the early part of this period included, however, a large number of Mammals belonging to genera or species now confined to the warmer regions of the globe, such as Rhinoceroses, Hippopotami, Elephants, Lions, Hyænas, &c.; and it was not till after the great cold of the glacial period that these generic types were finally swept away from the European area. In many other parts of the World the Pleistocene period was equally prolific in large forms of Mammalian life, more or less closely allied to those now inhabiting the same areas, of which we have remarkable instances in the extinct Edentates of South America and the Marsupials of Australia, many of which vastly exceeded in size their living relatives. Science has, indeed, yet to account satisfactorily for the disappearance of this exuberant life, and the consequently impoverished fauna among which we now dwell.

In regard to the Mammals of the Eocene, we have already remarked that they are frequently of a more generalised type than those now existing, and in many groups a well-marked progressive specialisation can be traced as we approach the existing epoch. Thus many of the Eocene Mammals possess the full Eutherian complement of forty-four teeth, which in the Ungulates were more uniform in size, less conspicuously differentiated into groups, and more approximated to one another than in recent forms. In the older Ungulates, moreover, the crowns of the cheek-teeth were relatively short; and we can trace a gradual increase in the height of the crowns as we advance in time, this increase affording a greater capacity to withstand wear, and thus indicating a greater length of life in the individual. In other instances we may observe a gradual reduction in the lateral digits of the typical pentedactylate limb, accompanied by a progressive elongation and strengthening of one or more of the remaining digits. Again, it has been shown that there has been a gradual increase in the relative size and the complexity of the brain as we approach the present day. Thus the Eocene Mammals, as a rule, had very small brains, in which the hemispheres left the cerebellum nearly uncovered, and were themselves nearly smooth, or but slightly convoluted; while in the higher forms the hemispheres spread backwards over the cerebellum, and are often marked by most complex convolutions. In some Eocene Ungulates the brain was so small that it could pass through the neural canal of the lumbar vertebræ.

Finally, it should be observed that we may trace a gradual evolution of local faunas. In the Eocene of any given region we find the Mammals differing widely in generic types from those now in-

habiting that area, yet as we ascend in the geological scale we trace a gradual approximation to the existing fauna; and in the Pleistocene we find the characteristic features of such fauna distinctly marked out, although many of the generic types, especially those including forms of large corporeal bulk, may be different. Examples of these features are afforded by the Marsupials of the Pleistocene of Australia, and the numerous Edentates of the same period in South America; although it is practically certain that in the former case the fauna has always been Marsupial, and therefore more or less closely related to the present one. That many of the existing Mammalian faunas now characteristic of particular regions were not thus circumscribed till a late period is, however, shown by the occurrence of Baboons, Hippopotami, Giraffes, and African types of Antelopes in the Pliocene and Pleistocene of India and parts of Europe; and equally by the Mammals of the Pleistocene of India being in many cases specifically identical with those of Africa, while the number of common species is now very few indeed. Again, many forms like the Rhinoceroses and Horses, which are now exclusively Old World types, formerly wandered over the plains of America, and thus point to a more uniform distribution of types than now exists. There are, however, indications of certain groups of Mammals having always been restricted to one hemisphere. Thus we have no evidence of the existence of Apes, Hyænas, or Civets at any epoch in the New World; and neither are there any traces of the Dinocerata or *Titanotheriidæ* in the Old World.

It was considered probable some years ago that the Mammalia were directly descended from some primitive Amphibian types, and that they stood altogether apart from the Reptiles. The striking resemblance of the pectoral girdle of the oviparous Monotremes to that of many Reptiles, and more especially the Anomodonts, together with the remarkable approximation to a low Mammalian type presented by the skeleton of the latter, renders it, however, more probable that Mammals are a divergent branch of the same Amphibian stock which gave origin to the last-mentioned group, if indeed they be not the direct descendants of the earlier forms of that group. Dr Baur, who considers that Mammals were developed from true Reptiles allied to the primitive Rhynchocephalia and Sauropterygia, has proposed that these early hypothetical forms should be termed Sauromammalia. Professor Mivart has, indeed, suggested that Mammals may have had a dual origin; and that while the Monotremes may have been derived at a comparatively late date from the Anomodonts or kindred types, the Marsupials may have originated at an earlier epoch from a totally distinct and perhaps Amphibian stock. Many objections have, however, been raised against this view; and Mr Poulton expresses his opinion that

"whether the Monotremes are the descendants of the ancestral Mammalia or not, it is quite certain that the higher Mammals must at one time have passed through a condition such as now exists in the Monotremes, in nearly all parts of their organisation; and many powerful arguments can be brought against the assumption that the same stage has been reached independently, and at widely separated periods, in the course of evolution." [1]

In the following chapters are given the leading palæontological characters of each order of the class, with the range in time of the different groups, and the names of the more important genera. The number of genera is, however, so great that only a very brief and general sketch of their characters and affinities can be given; special attention being drawn, where it may seem necessary, to those extinct types which are of more than ordinary interest from an evolutionary point of view.

[1] The opinion has been recently expressed by some Continental writers that the Cetacea are the most archaic type of Mammals, and that they have been directly derived from the Ichthyopterygian Reptiles. There is, however, so much evidence against this view that it may be considered as practically disproved.

CHAPTER LIX.

CLASS MAMMALIA—continued.

Orders Monotremata and Marsupialia.

Subclass I. Prototheria.—This subclass, now represented by only two genera, may be characterised as follows. The brain has a large anterior commissure, and a very small corpus callosum ;[1] while the auditory ossicles are simple, and the stapes is rod-like (columelliform). The coracoid is a distinct, although small, bone, anchylosing in the adult to the scapula, and articulating with the sternum ; while there is a separate precoracoid (epicoracoid), which does not articulate with the scapula, and also a large T-shaped interclavicle ; the form and relations of these bones being very like those of the corresponding parts of the skeleton in the Anomodont Reptiles. The pelvis has epipubic bones, and the ilia are inclined to the sacral axis after the Batrachian fashion ; thus resembling those of the Pariasaurian Anomodonts. The urinogenital and excretory organs open into a common outlet, or *cloaca ;* and the former are very similar to those of the Sauropsida ; the mammary glands are unprovided with nipples, and the reproduction is oviparous ; the eggs being meroblastic like those of Birds.

It may here be observed that the small bone in the pectoral girdle of the Monotremes placed in advance of the coracoid, which is usually termed the epicoracoid, appears to correspond with the precoracoid of the Anomodont Reptiles[2] (fig. 978 *bis*, p. 1054), although it does not extend upwards to articulate with the acromial process of the scapula, as the Anomodont precoracoid articulates with the process of the scapula identified by Sir R. Owen with the acromion.[3] Further, the scapula of the Monotremes differs from that of all other Mammals, and resembles

[1] The structure connecting the two hemispheres of the brain.

[2] This appears to be the view taken by Professor Cope.

[3] This is the original view. In describing the scapula of *Platypodosaurus*, Sir R. Owen confused the process situated above *a* in fig. 978 *bis* with that marked *a*, and termed the former the acromion.

that of Reptiles in that the acromion is situated on the anterior or preaxial border, which in the higher Mammals has become twisted round to the dorsal surface to form the spine of the scapula. The scapula of some of the Anomodont Reptiles appears to indicate how this torsion of the preaxial axial to form a ridge on the dorsal surface has taken place.

At the close of the preceding chapter reference has been made to the relationship of the Prototheria, or rather of its existing representatives the Monotremata, to Reptiles and Amphibia. The structure of the pectoral and pelvic girdles presents, indeed, so many striking resemblances to the same parts of the skeleton in the Labyrinthodont Amphibia and Anomodont Reptiles, as to indicate, as already mentioned, a distinct genetic connection between the three groups; the characters of the humerus apparently indicating

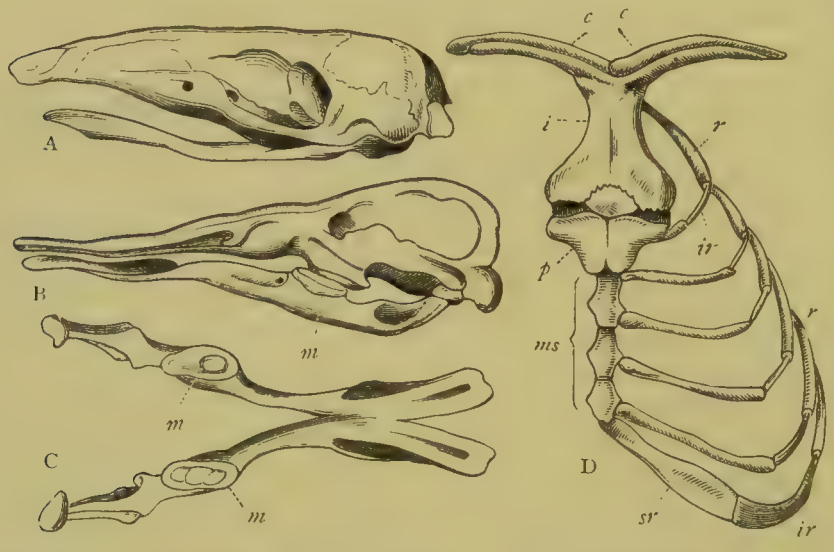


Fig. 1130.—A, Lateral view of skull of *Echidna*; B, Do. of *Ornithorhynchus*; C, Oral view of mandible of do.; D, Sternal region of do. *c*, Clavicle; *i*, Interclavicle; *p*, Presternum; *ms*, Mesosternum; *r*, Ribs; *sr*, Sternal ribs; *ir*, Intermediate ribs; *m*, Cornules. Reduced. (D after Flower; the others after Giebel.)

that the nearest relationship is with the Anomodonts. The deciduous teeth of *Ornithorhynchus* indicate, moreover, without any doubt that the ancestors of the Monotremes were provided with persistent teeth, which were probably monophyodont. Moreover, a distant resemblance between these deciduous teeth and the cheek-teeth of the extinct group, mentioned below under the name of Multituberculata, suggests that these forms may themselves be Prototheria. If this should prove to be the case, it would then be apparent that that branch of the subclass could not have been the ancestral stock of the Marsupials; and we shall accordingly have to look for another group or order of Prototheria, with a dentition akin to that of the Polyprotodont Marsupials. It is,

indeed, quite within the bounds of probability that the family *Dromatheriidæ* mentioned under the head of the latter group may prove to be Prototherians. And in any case it is quite evident that the two existing genera of Monotremes can in no way be looked upon as actual ancestral types.

Order 1. Monotremata.—As already mentioned, both the existing genera of Prototherians are included in this order, which may be provisionally characterised by the production of the cranium into a more or less elongated rostrum supporting a horny beak; by the absence of teeth in the fully adult animal; the smoothness of the brain-case; and the absence of an auditory bulla. The humerus is greatly expanded, and has an entepicondylar foramen; its whole contour approximating to the corresponding bone of the Anomodont Reptiles (fig. 982).

Family Ornithorhynchidæ.—In this family the cerebral hemispheres are smooth; the extremity of the muzzle is produced into a



Fig. 1131.—*Ornithorhynchus paradoxus*, Australia. Reduced.

broad beak-like expansion (fig. 1131); teeth are present in the young, and are succeeded by horny plates or cornules (fig. 1130, B, C); and the skin is covered with hair. The feet are webbed. This

family is represented solely by the genus *Ornithorhynchus* (fig. 1131), of which a single species inhabits the Australian rivers, in the banks of which its burrows are constructed. According to the observations of Mr O. Thomas, it appears that there are usually two teeth on either side of the upper and three in the lower jaw, which persist till the animal is somewhat more than one-third grown. These teeth have at first small but distinct roots, and present a distant resemblance to the true molars of some of the Multituberculata, like *Microlestes;* one of their longitudinal walls, or ridges, carrying a number of minute cusps. It appears that the cornules grow up beneath and around these teeth, which are gradually worn away, and finally shed like the milk-molars of other Mammals; the hollows in the cornules being the remnants of the original alveoli.

Family Echidnidæ.—The second family is characterised by the convoluted cerebral hemispheres; the production of the muzzle into a long tube-like beak (fig. 1130, A); the slenderness of the mandible; the total absence of teeth; and the presence of stout spines mingled with the fur. Further, the feet are very strong, and adapted for digging, and the centre of the acetabulum is imperfectly ossified. There are two living species found in Australia and New Guinea, both of which, at least for palæontological purposes, may be included in the genus *Echidna*, although the large *E. Bruijnii*, of New Guinea, is frequently separated under the name of *Proechidna*. Remains of a large species considerably exceeding the latter in size have been obtained from the Pleistocene of New South Wales.

Group Multituberculata.—In this place it will be convenient to notice a group of very imperfectly known Mesozoic and early Tertiary Mammals which were formerly regarded as Diprotodont Marsupials allied to *Thylacoleo*, but which differ in several respects from that group, and may perhaps eventually prove to be members of the subclass Prototheria. Although these peculiar forms resemble the Diprotodonts in having a single pair of lower incisors like those of Rodents, while many of them also approximate to certain members of the same group in having a secant and grooved fourth premolar; yet they differ in that it is the second in place of the first upper incisor which becomes enlarged and opposed to the incisor of the lower jaw; while when the fourth lower premolar is secant the summit of its crown is extremely convex instead of more or less concave. The true molars, as already mentioned, appear to approximate in general structure to the deciduous cheek-teeth of *Ornithorhynchus*, and are quite unlike those of any recent Marsupials. Till, however, the structure of the pectoral girdle be known the serial position of these forms cannot be definitely determined. And it may be observed, that the humerus of the limb which may be referable to *Tritylodon* is unlike that of the Mono-

tremata, so that if these forms be Prototheria they probably indicate a distinct specialised order of that subclass.

In addition to the features mentioned above, this group is characterised by the true molars (fig. 1136) carrying longitudinal rows of tubercles, separated by one or more grooves, and also by the absence of a pit or perforation in the masseteric form of the mandible.

FAMILY PLAGIAULACIDÆ.—In the *Plagiaulacidæ* the premolars, which vary in number from one to four in the mandible (figs. 1132–

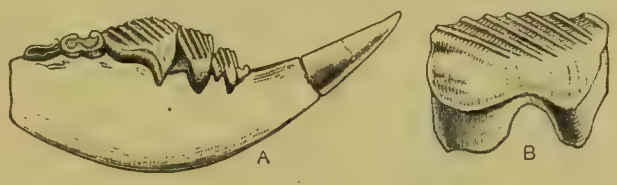


Fig. 1132.—A, Outer view of the right ramus of the mandible of *Plagiaulax minor;* four times natural size. B, Fourth lower premolar of *P. Becklesi;* five and a half times natural size. From the Purbeck of Dorsetshire. (After Owen.)

1138), are always of a secant nature, and are usually marked by a series of oblique lateral grooves (fig. 1132); while the true molars are small and reduced to two in number. In the type genus *Plagiaulax* of the Purbeck (Upper Jurassic) of Dorsetshire, there may be either four (fig. 1132), or three lower premolars; Professor Cope regarding the latter variation as indicating a distinct genus, for which he has proposed the name *Plioprion*. The upper teeth are unknown. *Ctenacodon* (fig. 1133), from the Upper Jurassic of North America, is a closely allied but perhaps less specialised type, with four lower premolars, which are much worn in the figured specimen. In the upper jaw the anterior premolars are like those of *Bolodon*. The figure shows the relatively low position of the condyle of the mandible in this family;—a feature shared with the Pleistocene *Thylacoleo*, among the Marsupials. From the Lowest Eocene, both of France and North America, we have the more specialised genus *Neoplagiaulax* (fig. 1134), in which only the fourth premolar remains in the mandible. The Puerco Eocene of North America has also yielded *Ptilodus* (fig. 1135), characterised by the

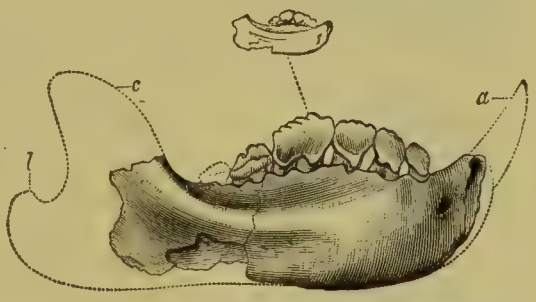


Fig. 1133.—Outer aspect of the right ramus of the mandible of *Ctenacodon serratus;* from the Upper Jurassic of North America. Upper figure, natural size; lower, four times natural size. *a*, Incisor; *b*, Condyle; *c*, Coronoid process. (After Marsh.)

presence of a minute third lower premolar. *Liotomus* of the French Eocene differs from all the others by its smooth fourth premolar. *Meniscöessus*, from the uppermost or Laramie Cretaceous of the United

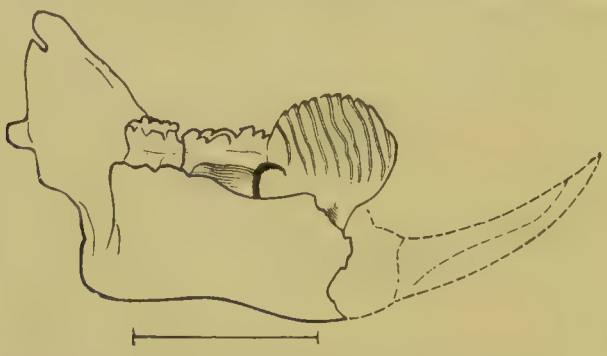


Fig. 1134.—Inner view of the left ramus of the mandible of *Neoplagiaulax eocænus*; from the Lower Eocene of Rheims. The line indicates the true size. (After Lemoine.)

States, is a somewhat larger form which may probably be included in this family. It was first made known by an upper true molar, but secant premolars from the same deposits subsequently described under the name of *Halodon*, together with other teeth figured under the names of *Tripriodon*, *Diprodion*, and *Selenacodon*, are probably all referable to *Meniscöessus*. Another form from the Laramie Cretaceous which may be provisionally known as *Cimoliomys*, appears to be closely allied to the Eocene *Ptilodus*, but may have affinity with *Plagiaulax*; the teeth described as *Cimolodon* and *Nanomys*, as well as one of those referred to *Halodon* appear inseparable from this form. Other generic names have been applied to teeth of a more or less closely allied type from the same deposits.

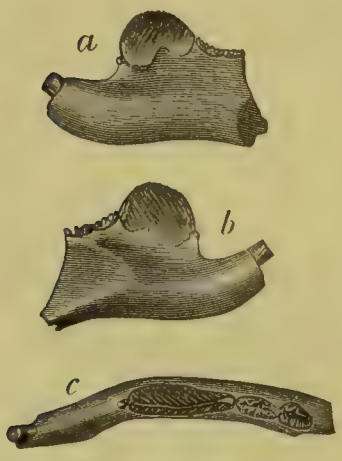


Fig. 1135.—The left ramus of the mandible of *Ptilodus mediævus*; from the outer (*a*), inner (*b*), and oral (*c*) aspects: from the Puerco Eocene of New Mexico. (After Cope.)

Certain bones from the Laramie described as *Camptomus* probably belong to this group, and are noteworthy as showing a distinct coracoid and interclavicle; thus, if rightly referred and determined, clearly indicating the Prototherian affinities of the Multituberculata.

From the Tertiaries of Patagonia Dr Ameghino has described certain remains under the generic names of *Abderites*, *Acdestis*, and *Palæotheutes*, which are referred to this family, and are apparently nearly related to the European genera. The genus *Microbiotherium*

has also been described from the same deposits, and is regarded as indicating a distinct family.

Family Polymastodontidæ.—The type genus *Polymastodon* occurs in the Lowest Eocene of North America, and has one premolar and two true molars. The premolar is tubercular, and the upper true molars have three longitudinal ridges, and are elongated antero-posteriorly.

Family Tritylodontidæ.—The genus *Tritylodon* was first described from a nearly entire cranium found in the Karoo system of South Africa, in a horizon which is probably of Lower Mesozoic age; but a tooth (fig. 1136) previously obtained from the Upper Trias of Germany, and described under the preoccupied name of *Triglyphus*, proves to belong to the same genus. The upper dental formula is *I.* 2, *C.* 0, *Pm.* 2, *M.* 4. The innermost upper incisor is large and scalpriform, while the outer one is very minute. The upper true molars (fig. 1136) carry three longitudinal ridges, and have the longer diameter of the crown directed transversely. The anterior portion of the cranium is remarkable for its great width and bluntness. The African species indicates an animal about the size of a Rabbit. From the same deposits at the Cape has been obtained a slab showing the impression of a pectoral limb apparently referable to a small Mammal, which has been described under the name of *Theriodesmus*. If, as is probably the case, this specimen be really Mammalian, there is, however, no reason why it should not belong to *Tritylodon*. According to Professor Bardeleben this limb has two centralia in the carpus (as in some Insectivora), and a distinct prehallux; the alleged fusion of the scaphoid with the lunar being incorrect. To the present family may likewise be referred the very imperfectly known *Stereognathus*, of the Lower Jurassic of Stonesfield; the upper cheek-teeth of which closely resemble those of *Tritylodon*. Finally, *Chirox*, from the Upper Jurassic of North America, shows certain characters connecting the present with the next family, in which it is provisionally placed by Professor Osborn.

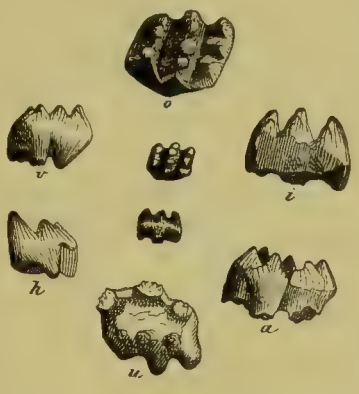


Fig. 1136.—An upper true molar of *Tritylodon Fraasi*; from the Upper Trias of Strasbourg. The two central figures are of the natural size; the others enlarged three times. *o*, Crown surface; *u*, Basal surface; *v*, *h*, The two lateral surfaces; *i*, *a*, Anterior and posterior surfaces. The position of *o* is at right angles to that of the molars in the next figure.

Family Bolodontidæ.—Nearly allied to the preceding family, but with the upper true molars antero-posteriorly instead of transversely elongated, and with only two longitudinal ridges, is the

genus *Bolodon*, of the Dorsetshire Purbeck. In this genus (fig. 1137) there were apparently three upper premolars and four true molars; with probably three incisors, of which the first is very minute. Although of much smaller size, the cranium of the type species presents a striking resemblance to that of the African *Trityl-*

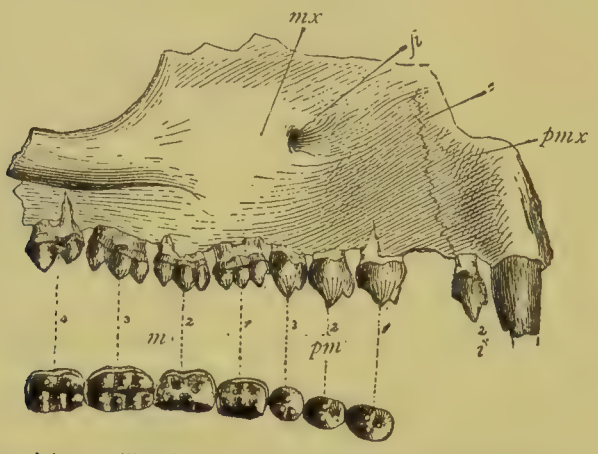


Fig. 1137.—The right maxilla of *Bolodon crassidens;* from the Dorsetshire Purbeck. *mx*, Maxilla; *pmx*, Premaxilla; *fi*, Foramen; *m*, True molars; *pm*, Premolars; *i*, Incisors. Greatly enlarged. (After Osborn.)

odon. *Allodon*, from the Upper Jurassic of North America, is a very closely allied, if not identical form, in which there were certainly three upper incisors, of which the second (fig. 1137) is enlarged, and apparently corresponds to the large inner incisor of *Tritylodon*. The genus *Microlestes*, from the Upper Trias of Würtemberg and England, is only known by detached molars (fig. 1138) closely resembling the true molars of *Plagiaulax*. This genus is referred by Professor Osborn to the *Plagiaulacidæ;* but till it is proved to have trenchant premolars it seems preferable to place it provisionally in the present family. Figure *a* in the accompanying woodcut gives a side view of the type tooth, which has two rows of tubercles separated by a longitudinal groove; the imperfect crown of another tooth shown in *b*, and provisionally referred to the same genus, is remarkable for the resemblance presented by its two remaining tubercles to those of the teeth of *Ornithorhynchus*. The name *Hypsiprymnopsis* has been applied to a tooth of *Microlestes*, from the English Rhætic.



Fig. 1138.—*a*, Lateral view of a tooth of *Microlestes antiquus;* *b*, Part of the crown of a tooth on a still more enlarged scale; from the Upper Trias of Würtemberg. (After Lyell and Falconer.)

Subclass II. Metatheria.—The members of this subclass agree with the Prototheria in the structure of the brain and the presence

of epipubic bones[1] (fig. 1139, *m*), but differ in the more specialised characters of the auditory ossicles; in the reduction of the coracoid to a mere process of the scapula, and its non-articulation with the sternum; in the absence of an interclavicle; and in the presence of nipples to the mammary glands. In the latter characters they agree with the Eutheria, from which they are distinguished by the presence of an imperfect cloaca, and by the characters of the urinogenital organs, which are in some respects intermediate between those of the Eutheria and Prototheria. The young, although produced viviparously, are born in an exceedingly imperfect condition, and are never nourished *in utero* by an allantoic placenta; but at an early period are transferred to the nipples of the mother, to which they adhere for a long time. The nipples themselves are nearly always concealed in a fold of skin forming the so-called *marsupium*.

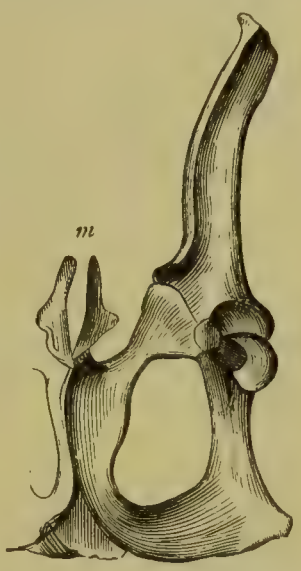


Fig. 1139.—Ventral view of the symphysis and left half of the pelvis of a Kangaroo. *m*, Epipubic bones. Reduced.

Teeth are invariably present, and are divisible into the usual four groups. With the exception of the *Phascolomyidæ*, the number of incisors in the upper jaw of all existing forms exceeds that in the mandible.[2] The true molars are very generally four in number on either side of each jaw; and in all existing forms the number of premolars does not exceed three, although four (which may be taken as the typical number) are found in several Mesozoic genera. The most remarkable feature about the dentition is, however, that it is only the last premolar (the fourth of the typical series) among the whole number of teeth that ever has a milk predecessor; such predecessor generally resembling the true molars in structure. Some genera, like *Phascolomys*, show, however, no signs of even this single replacement; and it is pretty clear that we have here the first commencement of a replacing series of teeth, which in the early Eutheria must have gradually extended anteriorly, until it normally embraced all the teeth in advance of *Pm.* 4, with the very general exception of *Pm.* 1, although in certain Perissodactyla even that tooth had a milk predecessor.

Another very characteristic, although not universal, feature in this subclass is the inflection of the angle of the mandible (fig. 1152);

[1] Unossified in *Thylacinus*.

[2] The same feature occurs among the Anomodont Reptiles in the *Galesauridæ*.

and in many genera the palatal region of the cranium contains unossified vacuities of considerable size.

Order II. Marsupialia.—The whole of the known Metatheria are included in the single order Marsupialia, and it is not at present necessary to give ordinal characters as distinct from those of the subclass. At the present day this order is restricted to America and the Australian region; the greater number of forms occurring in the latter area, while only the *Didelphyidæ* are found in the former. In earlier epochs, however, this order was much more widely distributed, and it apparently contains some of the earliest known representatives of the entire class.

Marsupials form in some respects the intermediate stage between the Prototheria and Eutheria, and it is probable that there will be eventually found a complete transition from the Polyprotodont suborder of this group to unknown Prototherian Mammals with the same general type of dentition—possibly more or less closely allied to the undermentioned Triassic family *Dromatheriidæ*.

Suborder 1. Polyprotodontia. — In existing Polyprotodont Marsupials, which occur both in America and the Australian region, there are never fewer than three lower and four upper incisors, and there may be five upper and four lower teeth of this series. These teeth are small and subequal, and are followed by a larger canine (fig. 1148). Normally there are three premolars, corresponding to the first, third, and fourth of the typical series, but the fourth may be absent, *Dasyurus* and *Sarcophilus* (fig. 1148). The number of true molars is generally four, but in *Myrmecobius* these teeth are increased to $\frac{5}{6}$; and their crowns are nearly always characterised by carrying a number of small, sharply pointed cusps. In no species is there a fourth premolar of the elongated secant form characteristic of many Diprotodonts. Several of the Mesozoic forms included in this group agree very closely with the recent ones, but many of them have four premolars, and in some there are as many as seven true molars.

Family Dromatheriidæ.—This family, typically represented by the genus *Dromatherium* (fig. 1140), of the reputed Trias of North America, is provisionally placed here, since it may be related to some of the members of the next family, although Professor Osborn makes it the type of a distinct order — the Protodonta — and even suggests that it may be Reptilian. If not Marsupials, these early Mammals may prove to be representatives of a group of Prototheria from which the Polyprotodont Marsupials have origin-



Fig. 1140.—Inner view of the left ramus of the mandible of *Dromatherium sylvestre*; from the Trias of North Carolina. (After Emmons.)

ated. The cheek-teeth differ from those of all other Marsupials in having the fangs imperfectly divided, and thus approximate to those of certain Anomodont Reptiles. There are seven true molars, the incisors are spaced, there is long diastema behind the canine, and the three premolars are of a very simple structure. The crowns of the true molars consist of one main cusp, with small accessory cusps; and it would appear that the teeth of the upper and lower jaws mutually interlocked. This type of tooth is regarded by Professor Osborn as the most archaic yet known. *Microconodon*, which occurs in the same deposits as *Dromatherium*, is an allied but smaller form.

Family Amphitheriidæ.—This Mesozoic family is provisionally taken to include a number of small and imperfectly known forms, some of which are regarded by almost all writers as undoubtedly Marsupials, although others have been referred by Professor Osborn, with some hesitation, to the Insectivora, under the name of Insectivora Primitiva; those which are retained by that writer in the present order being termed Prodidelphia. Although it is quite probable that with fuller information the two sections into which this family is divided may be raised to the rank of separate families, yet the evidence brought forward by the writer mentioned above in favour of referring some of the genera to the Insectivora appears to be insufficient; no members of that order having more than three lower incisors or more than the normal three molars of the other Placental Mammals.[1] Considerable confusion has arisen in regard to the dentition of many of the members included in this family owing to the circumstance that in the mandible only one side of the teeth is generally seen, so that several genera have been made upon the evidence of remains of a few closely allied species. The clearing up of this confusion is mainly due to the careful observations of Professor Osborn. In this family all the genera are characterised by a channel on the inner side of the mandibular rami known as the *Mylohyoid groove* (fig. 1147)—a feature occurring in many recent Polyprotodonts. The number of lower incisors was probably always four (as in the modern *Didelphyidæ*), and the lower true molars are frequently in excess of that number, as in *Myrmecobius* alone among existing heterodont Mammals. These true molars may either consist of three or more cusps arranged in a single line, or they may be differentiated into a tritubercular blade followed by a posterior heel or talon. The premolars are very generally four in number, but they may be reduced to three, or perhaps two. Not unfrequently, as in the existing *Peramelidæ*, the root of the canine may be grooved.

[1] Judging from his latest memoir on the subject, it is probable that Professor Osborn would now considerably modify his views as to these divisions.

As a provisional measure this family may be divided into two groups or subfamilies, of which the first may be eventually raised to the rank of a distinct family. The first subfamily, or *Phascolotheriinæ*, is referred by Professor Osborn to his Prodidelphia, and is included in the *Triconodontidæ* (*infra*). The lower true molars consist typically of three main cusps arranged in a line, together



Fig. 1141.—Inner view of the right ramus of the mandible of *Phascolotherium Bucklandi*; from the Stonesfield Slate. Twice natural size. The outline figure is natural size. There should be a fourth incisor. (After Owen.)

with some accessory cusps; and it would appear that the upper molars were of similar structure. The lower incisors are separated from one another by intervals. The typical genus *Phascolotherium* (fig. 1141), from the Lower Jurassic slate of Stonesfield, in Oxfordshire, has the condyle of the mandible placed very low down; the lower dental formula is *I.* 4, *C.* 1, *Pm.*+*M.* 7, the canine is separated by a diastema from the first premolar, and the true molars have a well-marked cingulum on the inner side. *Amphilestes* (fig.



Fig. 1142.—Reversed inner view of the left ramus of the mandible of *Amphilestes Broderipi*; from the Stonesfield Slate. Twice natural size. The restoration of the anterior teeth is conjectural; and the condyle is placed too high. (After Owen.)

1142), from the same deposits, has a more numerous series of cheek-teeth, and a higher mandibular condyle. The exact dental formula is not known, although it may have been the same as in the undermentioned *Amblotherium*. The mandible from the same beds shown in fig. 1143 has been made the type of the genus *Amphitylus;* and according to Professor Osborn has teeth of the

same general type as those of the preceding genera. If this be so, it would appear to countenance the view that the present group should be separated from the *Amphitheriidæ*, but owing to the damaged condition of the specimen great caution is necessary in speaking positively as to the nature of the teeth.

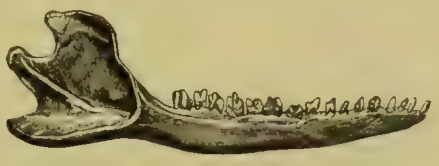


Fig. 1143.—Outer aspect of the right ramus of the mandible of *Amphitylus Oweni*; from the Stonesfield Slate. Enlarged. (After Owen.)

In the second subfamily, or *Amphitheriinæ*, the lower true molars are differentiated into a tritubercular anterior blade and a posterior heel or talon. Four premolars are present in all those genera of which the entire lower dentition is known; and the mandibular condyle is high. The upper molars are unlike the lower. Many of these genera are referred by Professor Osborn to his Insectivora Primitiva.

Before proceeding further some explanation is necessary as to the structure of this type of lower molar. Following the nomen-

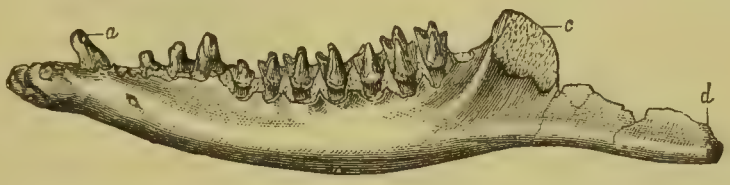


Fig. 1144.—Outer aspect of the left ramus of the mandible of *Dryolestes vorax*; from the Upper Jurassic of North America. Three times natural size. *a*, Canine; *c*, Coronoid process; *d*, Angle. The incisors and first premolar are absent. (After Marsh.)

clature adopted by Professor Flower the three cusps in the anterior half of such a "tritubercular" tooth may be collectively spoken of as the *blade* (fig. 1145, *a*, *b*, *c*); while the hinder part (*d*) may be termed the talon. In the blade the cusp *a* is termed the anterior,

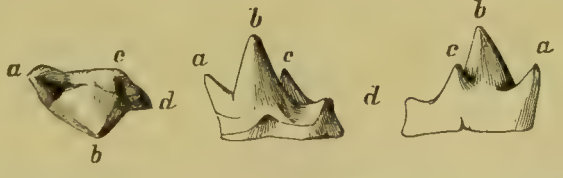


Fig. 1145.—Upper, outer, and inner views of a left lower true molar of *Dasyurus*. *a*, Anterior cusp of blade (*paraconid*); *b*, Posterior cusp of do. (*protoconid*); *c*, Inner cusp of do. (*metaconid*); *d*, Talon (*hypoconid*).

the large one *b* the posterior, and the small one *c*, which is the innermost, the inner cusp. According to Professor Osborn these three cusps correspond to the three cusps of *Priacodon* (fig. 1147), and in both cases he applies to them the names of *para-*, *proto-*,

and *metaconid;* calling the talon of the present type the *hypoconid.* Corresponding terms ending in *cone* are applied to the upper molars of the same types.

It will be obvious that when a jaw is embedded in matrix with the inner surface exposed we shall only see the cusps *a* and *c* and the talon *d;* while when the outer surface is visible only the large cusp *b* will be observed. An example of the latter occurrence is shown in fig. 1146; and this circumstance has been the fruitful source of error in regard to a number of the Mesozoic types under consideration.

In the type genus *Amphitherium* of the Stonesfield Slate, or Lower Jurassic, the exact dental formula is unknown, but it may perhaps have been the same as in the next genus.[1] In *Amblotherium* (= *Peraspalax*, *Phascolestes*) of the Purbeck, or Upper Jurassic, of Dorsetshire, the lower dental formula is *I.* 4, *C.* 1,

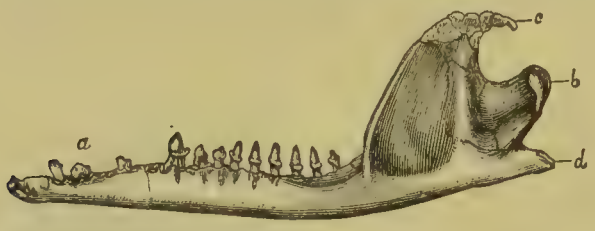


Fig. 1146.—Outer view of the left ramus of the mandible of *Amblotherium gracile;* from the Upper Jurassic of North America. Three times natural size. *a*, Canine; *c*, Coronoid process; *b*, Condyle; *d*, Mandible. (After Marsh.)

Pm. 4, *M.* (7–8), or the same as in the American Jurassic *Dryolestes* (fig. 1144). Several species are known, in some of which there were seven, and in others eight lower molars. The genus *Stylodon* has been founded upon the outer side of mandibles of *Amblotherium*, in which only the large posterior cusp (protoconid) of the blade of the molars is visible, as in the lower jaw shown in the accompanying woodcut, which has been made the type of the genus *Stylacodon*, of the Upper Jurassic of North America. The latter has eight lower molars, while the English form has only seven. *Achyrodon*, of the English Purbeck, is closely allied to *Amblotherium*, but differs in the form of the cusps of the molars. *Peramus* (*Leptocladus*) is a third Purbeck genus, with relatively stouter lower molars, in which Professor Osborn gives the lower dental formula as *I.* 3, *C.* 1, *Pm.* 6, *M.* 3. The North American *Dryolestes* has relatively shorter lower molars (fig. 1144), the woodcut clearly showing the three cusps of the blade and the talon of these teeth. *Asthenodon* and *Laodon* are other North American

[1] Professor Osborn regards it as *I.* ?, *C.* 1, *Pm.* 5, *M.* 6.

forms characterised by the small size of the talon of the lower molars; while the names *Dicrocynodon* (*Diplocynodon*), *Docodon*, and *Enneodon*[1] have been applied to more or less closely allied forms from the same deposits. Finally, Professor Osborn has given the name *Kurtodon* to certain upper jaws from the English Purbeck, which are probably referable to one or other of the above-mentioned genera. From the Laramie Cretaceous of North America Professor Marsh has described the remains of allied types. One of these has been termed *Didelphops* (*Didelophodon* or *Cimolestes*), while one tooth has been referred to the Jurassic genus *Dryolestes*, and another has been made the type of the genus *Pediomys*. The resemblance in the structure of the lower molars of the *Amphitheriinæ* to that of the corresponding teeth of *Dasyurus* and the *Didelphyidæ*, suggests that the latter have originated from an allied stock.

Family Spalacotheriidæ.—The genus *Spalacotherium*, with which *Peralestes* is identical, has a dentition which may probably be expressed by the formula *I.* $\frac{?}{3}$, *C.* $\frac{1}{1}$, *Pm.* $\frac{4}{4}$, *M.* $\frac{6}{6}$. The true molars consist of a single column carrying three cusps, and thus corresponding to the blade of the tooth of the *Amphitheriinæ*. The reduction in the number of the lower incisors distinguishes this family from the last; but it is difficult to say whether the absence of the talon in the lower true molars is or is not a more specialised feature. The molars, which are of the typical tritubercular type, approximate very closely in their plan of structure to those of the genus *Chrysochloris* among the Insectivora, but this cannot be taken as indicative that the present genus should be referred to that order, since a precisely analogous resemblance exists between the molars of *Tupaia* in the Insectivora and *Perameles* in the Marsupials. *Menacodon*, from the Upper Jurassic of North America, is an allied genus.

Family Triconodontidæ.—The last family of Mesozoic Mammals we have to consider is represented by the English Purbeck genus *Triconodon* (*Triacanthodon*), and the allied or identical *Priacodon* (fig. 1147) of the Upper Jurassic of North America. Professor Osborn includes in this family the *Phascolotheriinæ* already mentioned; but the reduction in the number of the incisors and the general *facies* of the teeth seems to indicate considerable difference—although the two groups are probably more or less nearly related. The mandibular condyle is placed still lower than in *Phascolotherium*, and apparently, indeed, than in any other known Mammal. The upper cheek-teeth resemble the lower. The dental formula in the mandible is *I.* 3, *C.* 1, *Pm.* 4, *M.* (3–4). The incisors were approximated, the cheek-teeth have

[1] Preoccupied, see page 1015.

an inner cingulum, and the molars consist of three subequal cones or cusps of a trenchant form, arranged longitudinally. There were apparently either three or four molars in different individuals of a single species. The fourth premolar was preceded by a milk-tooth resembling the true molars. It was considered by Sir R. Owen that the lower true molars of this genus corresponded to those of the existing *Thylacinus*, in which there is a bilobed blade and a talon. According, however, to Professor Osborn, this interpretation is incorrect; and that observer considers that the three cusps of the

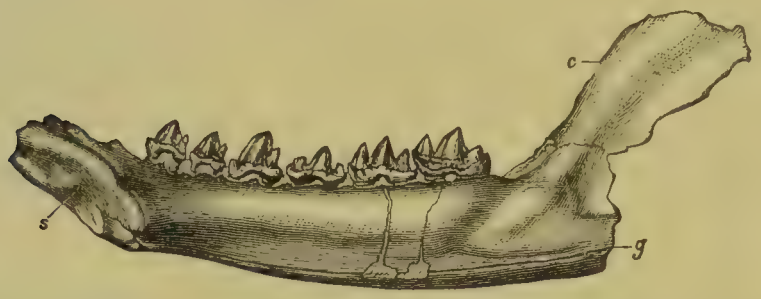


Fig. 1147.—Inner view of the left ramus of the mandible of *Priacodon ferox*; from the Upper Jurassic of North America. Three times natural size. *c*, Coronoid; *g*, Mylohyoid groove; *s*, Symphysis. The anterior teeth are wanting. (After Marsh.)

Triconodont type represent the three main cusps of the tooth of *Phascolotherium* (fig. 1141), and also correspond to the three lobes of the blade of the tritubercular molar of the *Amphitherium* type (fig. 1145); and he accordingly terms these three cusps the *para-*, *proto-*, and *metaconid*, and considers that the talon (*hypoconid*) is unrepresented.

Family Dasyuridæ.—With this family we come to the consideration of the existing Marsupials. The *Dasyuridæ* is an exclusively Australian family, comprising the largest known members of the suborder, and is divided into the subfamilies *Dasyurinæ* and *Myrmecobiinæ*. These are always $I.\ \frac{4}{3}$, $C.\ \frac{1}{1}$; but the number of cheek-teeth varies, although there are never more than three premolars. In the pes the hallux is usually either rudimental or absent, but the other four digits are well developed and subequal. In the *Dasyurinæ* the number of cheek-teeth does not exceed $\frac{7}{7}$, the upper true molars have triangular crowns, and those of the lower molars are differentiated into an anterior blade and a posterior talon (fig. 1145), like the lower carnassial tooth of many of the placental Carnivora of the present day. The mylohyoid groove may be present both in this and the next subfamily. The Tasmanian Wolf is the sole living representative of the genus *Thylacinus*, in

which the cheek-teeth number *Pm.* $\frac{3}{3}$, *M.* $\frac{4}{4}$, and the humerus has a foramen; but in the Pleistocene of Australia there occurs the considerably larger *T. spelæus*. *Sarcophilus*, of which the dentition is shown in fig. 1148, is also confined at the present day to Tas-

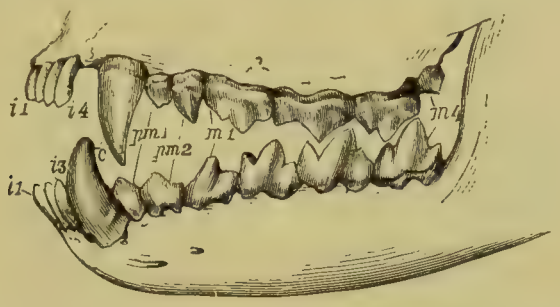


Fig. 1148.—Left lateral view of the dentition of *Sarcophilus ursinus*. Recent, Tasmania. *i*, Incisors; *c*, Canine; *pm*, Premolars; *m*, Molars. The tooth marked *pm* 2 is really *pm* 3.

mania, but a larger species inhabited the mainland of Australia in the Pleistocene. Indications of specialisation are shown by the reduction of the premolars to two, and also by the loss of the foramen in the humerus. The most generalised genus of the subfamily is *Dasyurus*, comprising several species of smaller size than the preceding. In the lower molars (fig. 1145) the blade has three cusps arranged in a triangle, and thus differs from those of *Thylacinus*, in



Fig. 1149.—*Myrmecobius fasciatus*, Australia. Reduced.

which the inner cusp is wanting. There is a mylohyoid groove in the mandible, and the humerus has a foramen. Species of *Dasyurus* at the present day range over the whole of the Australian continent, one of them dating from the Pleistocene. The subfamily *Myrmeco-*

biinæ is represented solely by the genus *Myrmecobius*. In this remarkable animal (fig. 1149) the lower incisors are separated from one another, the cheek-teeth number $\frac{8}{9}$, of which the first three in either jaw are premolars; while the molars have quadrangular multicuspidate crowns, and are not well differentiated from the premolars. Although some writers doubt the connection, it is probable that *Myrmecobius* is the direct descendant of forms closely allied to *Amphilestes*, of the Lower Jurassic of England; the relations of the two being perhaps somewhat similar to that existing between the living *Sphenodon* of New Zealand, and the more specialised *Hyperodapedon* of the English Trias.

Family Peramelidæ.—In this family, comprising the Bandicoots of Australia and New Guinea, the dental formula is $I.\ \frac{(4-5)}{3}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{3}{3}$, $M.\ \frac{4}{4}$, and the pes has two of the digits reduced and connected by integument, as in the *Macropodidæ* among the Diprotodonts. Occasionally the canines have grooved or double roots. Remains of existing species of *Perameles* and *Peragale* occur in the Pleistocene of New South Wales.

Family Didelphyidæ.—In all the members of this family the dental formula is $I.\ \frac{5}{4}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{3}{3}$, $M.\ \frac{4}{4}$. The incisors are very small and sharp; the canines are large; the premolars compressed; and the true molars constructed on the general plan of those of



Fig. 1150.—Left lateral view of the dentition of *Didelphys Azaræ*; South America. *i*, Incisors; *c*, Canine; *pm*, Premolars; *m*, True molars. The teeth marked *pm* 3 should be *pm* 4; the teeth between these and *pm* 1 being *pm* 2.

Dasyurus; the lower ones having a blade and talon, with a distinct inner cusp to the former. Each foot is furnished with five complete digits; and the humerus has an entepicondylar foramen. At the present day the Opossums, as the members of this family are commonly called, are confined to the New World, where they are represented by the genera *Didelphys* (fig. 1150) and *Chironectes*;

the latter being known only by a single species. Remains of existing species of both genera occur very commonly in the Pleistocene breccias of the Brazilian caves; and to the type genus may also be referred a large number of species from the Lower Miocene and Upper Eocene of Europe, which by some writers are referred to distinct genera under the names of *Peratherium* and *Amphiperatherium*. *Spalacodon*, of the Eocene of Hordwell, is probably a *Didelphys*. It was in *Didelphys Cuvieri*, of the Paris gypsum, that

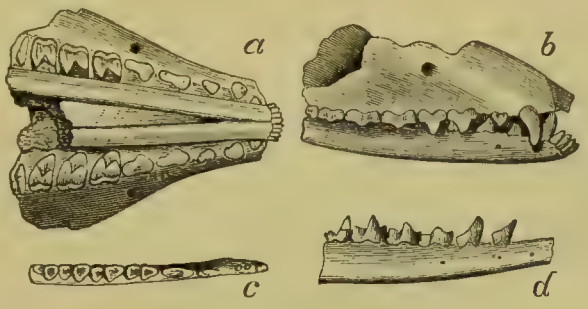


Fig. 1151.—*Didelphys* (?) *fugax*; from the White-river Miocene of Colorado. Twice natural size. *a*, *b*, Inferior and lateral views of skull; *c*, *d*, Superior and lateral views of right mandibular ramus. (After Cope.)

Cuvier demonstrated the existence of marsupial bones by a careful clearing of the matrix. Other extinct forms from the Miocene of North America (fig. 1151) may in all probability be referred to the same genus.

Suborder 2. Diprotodontia.—If we exclude the Multituberculata, which have been already mentioned, this suborder will be confined to the Australian region, where it has been known since the Pleistocene; and with this limitation it may probably be regarded as an offset from the more generalised Polyprotodontia. In all cases there is only a single pair of lower incisors, but in the upper jaws there are usually three pairs of such teeth, although they are reduced to one in the Wombats. The lower incisors, and the first, or innermost, pair of upper incisors are always of large size and adapted for cutting. The canines are frequently absent, and when present are of relatively small size. The crowns of the true molars are either tuberculate or have transverse ridges; and as a general rule there are not more than two premolars. Very frequently the last premolar has a long and narrow crown, with a concave superior border adapted solely for cutting.

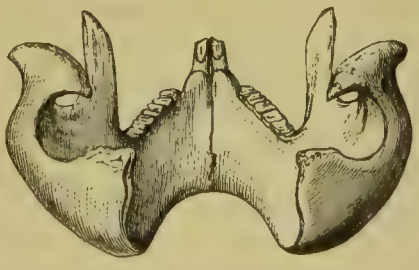


Fig. 1152.—Posterior reduced view of the mandible of the Wombat (*Phascolomys*).

Family Phascolomyidæ.—This family is now represented only by the genus *Phascolomys*, or Wombats; in which the dental formula is *I.* $\frac{1}{1}$, *C.* $\frac{0}{0}$, *Pm.* $\frac{1}{1}$, *M.* $\frac{4}{4}$, and all the teeth grow from persistent pulps. The true molars have curved crowns consisting of two subequal lobes, while the premolar has only a single lobe, and is not preceded by a milk-tooth. The mandible (figs. 1152, 1153) is characterised by having a pit and perforation in the masseteric fossa. The fore and hind limbs are of equal length, the former being of great strength in accordance with the fossorial habits of the genus; and the humerus has a foramen. There are five digits in the manus, all of which are provided with long curved claws, and are of subequal size; but in the pes the hallux is imperfect, and the three middle digits are of nearly equal size, and partly enclosed in a common integument. Three existing species of Wombat are known, which are divided into two groups according to the char-



Fig. 1153.—Left lateral view of skull of Wombat (*Phascolomys latifrons*). Reduced. Australia.

acters of the skull and teeth; none of them being of large size. In the Pleistocene of Australia we meet with remains not only of these existing species, but also with several extinct types, one of which was of considerably larger dimensions. In the same deposits are also found remains of the extinct genus *Phascolonus* (with which the so-called *Sceparnodon* appears to be identical), characterised by certain peculiarities in the incisors. The one known species probably attained the dimensions of a Tapir, although of considerably stouter build.

Family Nototheriidæ.—This family is represented only by a single definitely known genus from the Australian Pleistocene described as *Nototherium*.[1] This includes one (or possibly more) large

[1] It has recently been suggested that the figured skull does not belong to *Nototherium*, and that it should be termed *Zygomaturus;* but this view is not sup-

species, and appears to have been allied in many respects to the Wombats, although presenting several of the dental characters of the next family. The dental formula is $I.\ \frac{3}{1}$, $C.\ \frac{0}{0}$, $Pm.\ \frac{1}{1}$, $M.\ \frac{4}{4}$; and it appears that, at least normally, there was no deciduous milk-molar. The cheek-teeth are rooted; the crowns of the true molars carrying two simple transverse ridges. The cranium (fig. 1154) presents a very singular contour, the nasals being transversely expanded; and the mandible differs from that of the *Phascolomyidæ*

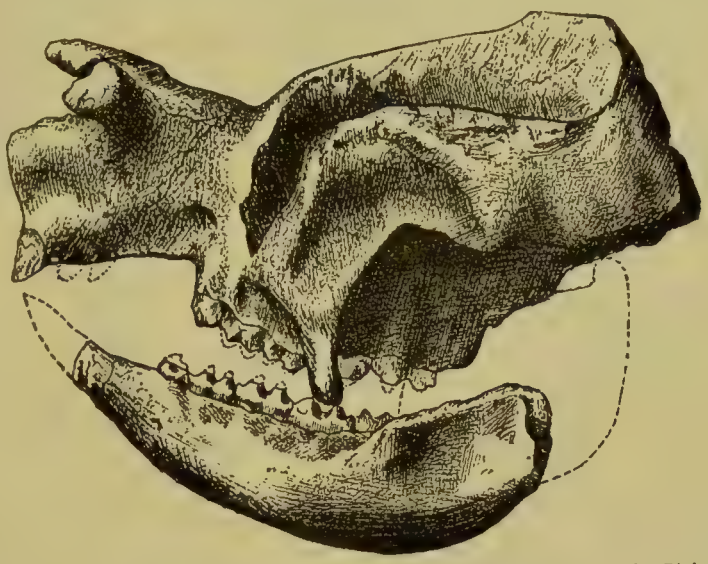


Fig. 1154.—Left lateral view of the skull of *Nototherium Mitchelli*; from the Pleistocene of Australia. One-sixth natural size. (After Owen.)

by the absence of a pit or perforation in the masseteric fossa (fig. 1154). The limb-bones appear, however, to have resembled those of the latter family; the humerus having a distal foramen, and being evidently adapted for fossorial habits, although it is difficult to believe that an animal of such comparatively large bulk could have lived in burrows.

Family Diprotodontidæ.—The genus *Diprotodon*, of the Australian Pleistocene, is the sole representative of this extinct family, and the type species (fig. 1155) is the largest known member of the order; its bulk being fully equal to that of a large *Rhinoceros*. The dental formula is the same as that of *Nototherium*; and the structure of the cheek-teeth of the two genera is also very similar, although the lower true molars of *Diprotodon* have no median longitudinal bridge. In the incisors of this genus the first pair are

ported by sufficient evidence. A small Nototheroid from Queensland has received the preoccupied name *Owenia*.

scalpriform, and grow from persistent pulps. The fore and hind limbs are of approximately equal length, and adapted solely for walking; the humerus has no foramen; and it is probable that the covering of the toes approximated to the nature of hoofs. The mandible, although more convex below, is not unlike that of *Nototherium*. Professor Huxley has named a second species on the

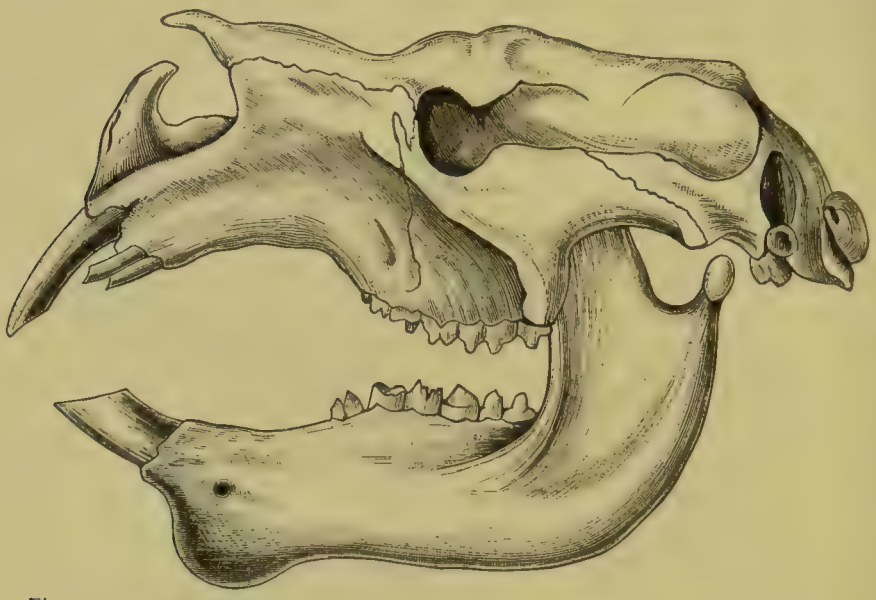


Fig. 1155.—Left lateral view of the skull of *Diprotodon Australis*; from the Pleistocene of Australia. Much reduced. (After Owen.)

evidence of premolars, but it is not certain that this determination is correct.

Family Phalangeridæ. — This family includes the existing Phalangers and the Koala (*Phascolarctus*), as well as a remarkable extinct genus. All these animals have $I.\ \frac{3}{1}$, and an upper and frequently also a minute lower canine; while the premolars may vary from $\frac{2}{1}$ to $\frac{3}{3}$, and the true molars from $\frac{1}{2}$ to $\frac{4}{4}$. The structure of the cheek-teeth is subject to great variation in the different genera; the fourth premolar being either secant or tubercular. There is no pit or perforation in the masseteric fossæ of the mandible. The limbs are of nearly equal length; the manus has five subequal digits, but the second and third digits of the pes are very slender and partially united by integument; and the hallux is always opposable. In many of the true Phalangers the fourth premolar is grooved, and the dentition closely resembles that of the existing genus *Hypsiprymnodon* among the *Macropodidæ*. Of living genera the only one

known to occur in a fossil state is *Pseudochirus*, of which the remains of an existing species are found in the Pleistocene cave-deposits of New South Wales. The most interesting member of the family is, however, the large Pleistocene *Thylacoleo* (fig. 1156), which forms the type of a distinct subfamily. The dentition may be represented by the formula $I.\frac{3}{1}$, $C.\frac{1}{0}$, $Pm.\frac{3}{3}$, $M.\frac{1}{2}$. The true molars and earlier premolars were small, and more or less functionless, while the fourth premolar is enormously developed, and has a long sharp cutting-edge, so that, in union with its fellow of the opposing jaw,

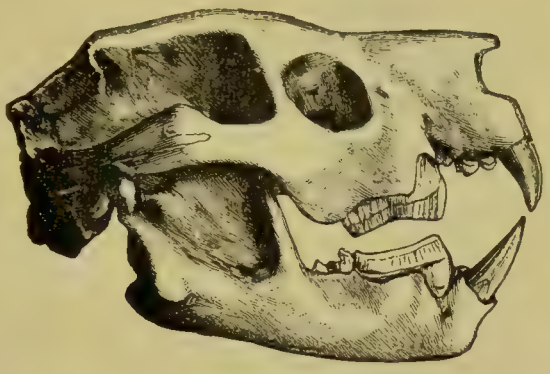


Fig. 1156.—Right lateral view of the skull of *Thylacoleo carnifex;* from the Pleistocene of Australia. One-fifth natural size.

it forms a cutting instrument of extraordinary power. In originally describing this remarkable animal from fragments of jaws containing the fourth premolar, Sir Richard Owen came to the conclusion that the structure of this tooth indicated a carnivorous animal adapted to prey upon the huge Diprotodons and Nototheres; but the discovery of the complete skull has shown that the animal was more closely allied to the existing Phalangers, and that it could not have possessed the destructive habits attributed to it by its describer, although it is quite probable that its diet may have included the smaller mammals, birds, and eggs. It was at one time considered that the Multituberculata were allied to this genus.

Family Macropodidæ.—The last, and in many respects the most specialised family of the Diprotodontia includes the Kangaroos, Wallabies, and Kangaroo-rats. The dentition is represented by the formula $I.\frac{3}{1}$, $C.\frac{(0-1)}{0}$, $Pm.\frac{2}{2}$, $M.\frac{4}{4}$. The incisors are extremely secant, those of the mandible being frequently movable against one another. The premolars may have either triangular or cutting crowns, and in the latter case (fig. 1158) are frequently grooved; the third premolar is always, and the fourth in some cases,

deciduous, the latter being invariably preceded by a milk-tooth. The true molars have either four tubercles or two transverse ridges, and frequently an anterior talon. The mandible has a deep pit and perforation in the masseteric fossa. The pectoral limb is always more or less markedly shorter than the pelvic. The manus is provided with five subequal digits; but in the pes (fig. 1157) the hallux is generally absent, the second and third digits being very minute and enclosed in a common integument (*syndactylous*), while the fourth is greatly enlarged, and forms the main base of support. The majority of forms progress by making enormous leaps by means of their powerful hind-limbs; but a few, like *Dendrolagus* of New Guinea, are arboreal. This family may be divided into three subfamilies. In the first, or *Hypsiprymnodontinæ*, there is a distinct hallux, and the dentition closely resembles that of the *Phalangeridæ;* the fourth premolar being small, obliquely grooved, and directed inwardly at its anterior border. In the small existing *Hypsiprymnodon* there is no tooth between the lower incisor and the fourth premolar; but in a large extinct form from the Pleistocene of New South Wales, described under the name of *Triclis*, there is a minute tooth behind the lower incisor corresponding to the tooth in the *Phalangeridæ* commonly reckoned as the representative of the canine. This genus, therefore, forms an important link between the last-named and the present family. In the second subfamily, or *Potoroinæ*, the hallux is absent; the first upper incisor is narrower and longer than either of the others (fig. 1158); there is always an upper canine; the fourth upper premolar is elongated and secant, and usually with the grooves strongly marked; while the true molars are tuberculate, with the fourth smaller than the third. The Kangaroo-rats are divided into the genera *Potorous* (*Hypsiprymnus*), *Bettongia*, and *Æpyprymnus;* the latter being represented in the Pleistocene of New South Wales by remains of the existing species.



Fig. 1157. — Dorsal aspect of the right pes of *Macropus Bennetti*. Reduced. (After Flower.)

The third subfamily, or *Macropinæ*, is distinguished from the last by the following characters: The cutting-edges of the upper incisors form nearly a straight line (fig. 1159); the upper canine is usually either absent or very small; and the fourth premolar, which may be shorter or longer than the first true molar, has either an inner basal ridge or lobe. In the existing genus *Macropus* (Kangaroos) the fourth upper premolar has a sharp cutting outer edge, and an inner ridge or tubercle; and this tooth in both jaws may be either longer or shorter than the first true molar. The two rami of the mandible

are not anchylosed together, and the hind-limbs are much longer than the front ones. A large number of fossil species occur in the Australian Pleistocene, among which may be mentioned several very large forms like *M. brehus*, which have the fourth premolar longer than the first true molar, and are allied to the small existing Wallaby, *M. ualabatus* (which also occurs in the Pleistocene).

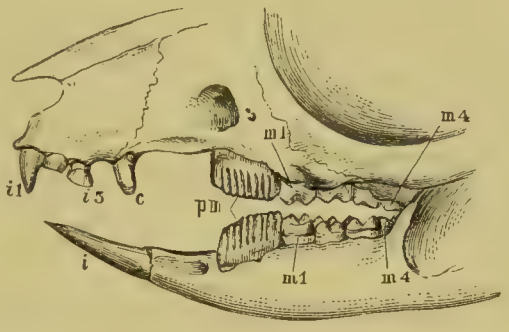


Fig. 1158.—Dentition of *Potorous*. *i*, Incisors; *c*, Canine; *pm*, Premolar; *m*, Molars.

Then, again, we have in the same deposits remains of the existing Rock-Kangaroo, *M.* (*Petrogale*) *penicillatus*, and also of the larger *M. robustus*, and some allied extinct forms. Another group, in which the fourth premolar is very small and soon falls out, is represented by the existing *M. giganteus*, and the larger extinct *M. titan* and *M. ferragus*. *Sthenurus* is an entirely extinct genus characterised by the presence of a distinct inner lobe to the fourth upper premolar, and is represented by a single species of considerable size. In *Procoptodon*, again, which is likewise extinct, the fourth

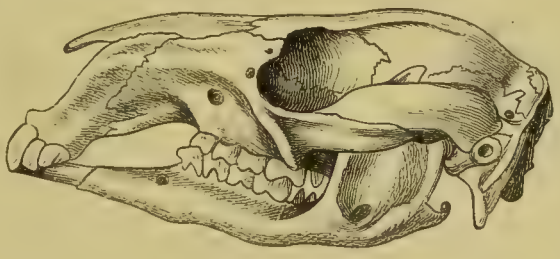


Fig. 1159.—*Macropus Bennetti*. Lateral view of skull; from Australia. Reduced.

upper premolar is like that of *Sthenurus*, but the rami of the mandible become anchylosed together in the adult; more than one species are known. Finally, the extinct *Palorchestes*, comprising the largest known member of the family, is distinguished from the last-named genus by the longer mandibular symphysis, and the absence of an anterior talon in the upper true molars. The length

of the skull of the one known species is estimated at as much as sixteen inches.

Of Uncertain Ordinal Position.—Here may be conveniently noticed some minute Mammals, mostly known by teeth or fragments of jaws, from the Lowest Eocene of Rheims, of which it is difficult to say whether they are Marsupial or Placental, although it is highly probable that some of them belong to the former division. Among these may be mentioned *Tricuspodon*, with teeth resembling those of *Spalacotherium;* the allied *Orthaspidotherium* and *Pleuraspidotherium;* and *Procynictis*, in which the true molars approximate to those of *Amblotherium*.

CHAPTER LX.

CLASS MAMMALIA—continued.

Orders Edentata, Cetacea, and Sirenia.

Subclass II. Eutheria.—The whole of the remaining orders of Mammalia are grouped together in a single subclass,[1] which is characterised by the fœtus being nourished *in utero* by means of the maternal blood passing through an allantoic placenta. This subclass is sometimes termed the Placentalia, but more generally the Eutheria. Throughout this subclass the urinogenital organs are provided with an external aperture quite distinct from that of the alimentary tube; the corpus callosum of the brain is well developed; there is never any marked inflection of the angle of the mandible; and distinct epipubic bones are absent in the pelvis. With the exception of the three orders forming the subject of the present chapter, the dental formula can always be reduced to some modification of that given on page 1249. At the present day the various orders have become so well differentiated as to render their definition comparatively easy; but fossil forms indicate such a close connection between the majority of them, that such definition becomes frequently a matter of extreme difficulty, if not an absolute impossibility; and it is to be remembered that it is entirely due to our non-acquaintance with forms which must have once existed that renders even these imperfect definitions practicable.

There is at present no conclusive evidence of the existence of any member of this subclass previous to the Eocene.

Order III. Edentata.—The Edentata are widely different from all other existing Mammals, although there are indications of affinity to certain extinct forms mentioned in the sequel under the heading of the Tillodontia. Almost the only common character presented by the various existing members of this order is that the teeth, when

[1] It has, indeed, been proposed to form a separate subclass—Paratheria—for the reception of the Edentates.

present, are devoid of enamel, are never developed at the extremities of the jaws in the situation of the incisors of other Mammals, and are always homœodont and grow from persistent pulps; while, with the exception of one genus of the *Dasypodidæ*, they are likewise monophyodont. It has, however, been recently observed by Dr Ameghino that enamel was present in the teeth of certain South American fossil forms; while in the genus *Diadomus*, from those deposits, a pair of canine-like teeth occur in the symphysis of the mandible. In many of the genera the teeth are simply cylindrical, but they may be transversely ridged, and occasionally they have a very complex internal structure. Not unfrequently the maxillary bone sends down a large descending process in the zygomatic arch (fig. 1163 *bis*); and certain members of the order are remarkable as being the only known Mammals which develop a bony exoskeleton. The cervical vertebræ are short and wide, with nearly flat terminal faces to their centra.

The distribution of the Edentates is very restricted. In Europe neither at the present day nor in past times is there any known representative of the order; the so-called *Macrotherium* being now known to be identical with the Ungulate genus *Chalicotherium*, while *Ancylotherium* is also allied to the latter. In tropical Asia we find the Pangolins or *Manidæ;* and in Africa the *Orycteropodidæ*. South America is, however, the headquarters of the order, which is there represented at the present day by the Anteaters, the Sloths, and the Armadillos, and in past epochs by the huge Ground-Sloths and the Glyptodonts. The gigantic size of these fossil forms as compared with their existing allies of the same area is paralleled by the instance of the fossil Diprotodont Marsupials of Australia.

It is evident that the Edentates are widely separated from all other existing Eutherians; and Professor W. K. Parker, in view of the tendency to a variation in the number of cervical vertebræ and other features, has suggested a separate origin from a Prototherian stock. Professor Cope, however, looks upon the order as allied to the Tillodonts, and the occurrence of enamel in the teeth of some fossil forms may support this view.

Family Orycteropodidæ. — The Ant-Bears (*Orycteropus*) of Africa are characterised by the body being covered merely with a few hairs; and by the numerous teeth, which are of a remarkably complex structure, owing to the presence of a number of vertical pulp-canals. In the fore-limb the pollex is absent, but the hind-limb has five digits. The femur has a third trochanter, and the terminal digits are provided with moderate-sized claws, suitable for digging the burrows in which these creatures dwell. At the present day *Orycteropus* is mainly characteristic of the Ethiopian region, although one of the two species ranges into Egypt. Till very re-

cently nothing was known of the palæontological history of the family, but Dr Forsyth-Major has recorded a species from the Lower Pliocene of the isle of Samos, in the Turkish Archipelago, distinguished from the existing species by the larger size of the lateral



Fig. 1160.—Lateral view of the skull of *Orycteropus capensis*. Africa. Reduced.

metatarsals. The occurrence of this species seems to point to the conclusion that Asia was the original home of the family.

Family Manidæ.—The Pangolins (*Manis*) of India and Africa are distinguished from all other Mammals by the body being covered superiorly with a coat of imbricated, horny, epidermal scales. Teeth are absent; the limbs are short and furnished with five digits, of which the terminal claws are long, curved, and bifid at the extremities. The humerus has an entepicondylar foramen, but there is no third femoral trochanter, and clavicles are wanting. The large *Manis gigantea* of Western Africa is found in a fossil state in the Pleistocene cave-deposits of Southern India; while in the Lower Pliocene of the isle of Samos we have a species three times the size of the latter, which has been made the type of the genus *Palæomanis*. A phalangeal from the Indian Siwaliks described as *Manis* appears to belong to *Chalicotherium*.

Family Dasypodidæ.—The Armadillos (fig. 1161) of South America are characterised by the presence of a bony dorsal carapace, composed of a series of dermal scutes, of which a certain number are always arranged in movable bands, while the others may be articulated together into solid scapular and pelvic bucklers, as in fig. 1161. The frontal region of the skull also has a buckler; while the tail is defended by rings or tubercles of bone. In the existing genera the teeth are simply conical; and in *Tatusia* all except the last have milk predecessors. Many of the cervical vertebræ are anchylosed together; and the stout humerus has an entepicondylar foramen, and the femur a third trochanter. The fore-feet are provided with very strong curved claws; and, like the *Manidæ*, the existing forms are of burrowing habits. The Pleistocene cave-deposits of Brazil yield remains of some existing and some extinct

species of the genera *Dasypus*, *Tatusia*, *Tolypeutes* (fig. 1161), and *Xenurus*. In the Pleistocene of Argentina we meet with a large extinct type known as *Eutatus*, which is characterised by the whole of the carapace consisting of movable bands, which are thirty-three in number. The Tertiaries of the same region have also yielded a much larger form known as *Dasypotherium*, which appears to connect the living forms with the next genus. There were eight lower teeth, of which the second appears to have been enlarged, as in some species of *Mylodon*. The most remarkable genus is, however,

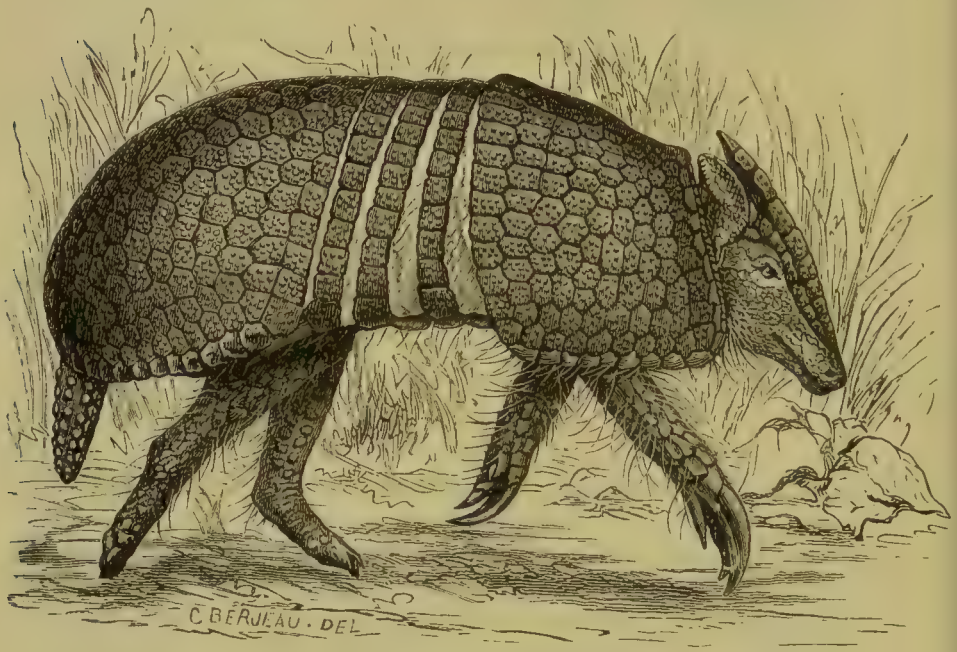


Fig. 1161.—The three-banded Armadillo (*Tolypeutes conurus*). South America. One-third natural size. (After Murie.)

Chlamydotherium, of the South American Pleistocene, in which the teeth approximate in structure to those of the next family. The carapace has several movable bands; and the largest species is considered to have equalled the bulk of a Rhinoceros. The existing Armadillos are therefore dwarfs by the side of these huge allies of an earlier epoch.

Family Glyptodontidæ.—In this extinct American family the body was covered by a carapace as in the Armadillos; but this carapace (fig. 1162) has no movable bands, so that the animal could not roll itself up; and since the fore-feet have short thick toes, it is evident that the habits of this group were not fossorial. The carapace usually has its component scutes united by suture, but in one genus they were separate; the scutes are, moreover, usually ornamented with a sculpture, which varies in the different

genera and species; but they may be either plain or tuberculated. There is usually a ventral buckler (never found in the Armadillos),

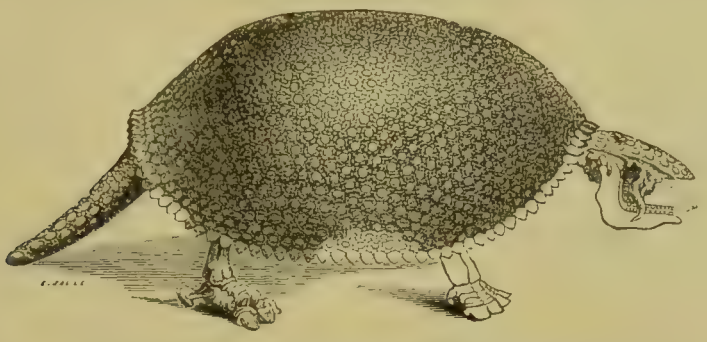


Fig. 1162.—*Glyptodon clavipes;* Pleistocene, South America. Reduced greatly. The tail is incorrectly restored, and it is probable that the figured portion belongs to *Hoplophorus*.

and the tail is enclosed in a complete bony sheath. The teeth are $\frac{8}{8}$ in number, and have two deep grooves on either side dividing them into three nearly distinct lobes (fig. 1163); the generic name being derived from this grooving or fluting. The facial part of the cranium is characterised by its extreme shortness (fig. 1163 *bis*); and there is a long descending maxillary process in the zygomatic arch. Nearly the whole of the vertebral column is anchylosed into a long tube, but there is a complex joint at the base of the neck. This family is mainly characteristic of South America; but species of *Glyptodon* ranged as far as Mexico and Texas into North America. Great confusion has arisen in respect to the classification of the Glyptodonts, owing to the difficulty of referring isolated caudal sheaths to their proper carapaces. The forms with a solid carapace may, however, be arranged as follows. In *Hoplophorus* the scutes of the carapace are sculptured, and often comparatively thin, the peripheral series being flat; while the caudal sheath has several movable rings, and terminates in a long



Fig. 1163.—Grinding surface of two teeth of *Glyptodon reticulatus;* from the Pleistocene of South America.



Fig. 1163 *bis*.—Left lateral view of the skull of *Glyptodon;* from the Pleistocene of South America. One-tenth natural size. (After Burmeister).

subcylindrical tube (fig. 1164), ornamented with a number of large disks, surrounded by a series of much smaller ones. It is considered probable that the caudal tube represented in fig. 1162 belongs to this genus. The humerus has an entepicondylar foramen, and there are four complete digits to each foot. An allied form, from the infra-Pampean of Patagonia, has received the name of *Palæhoplophorus;* while the terminal tube of a caudal sheath from Uruguay has been made the type of the genus *Eleutherocercus*. The latter specimen is characterised by its loose attachment to the enclosed vertebræ, and by the great number of perforations for bristles, so that the tail of the living animal must have resembled a huge bottle-brush. The genus *Panochthus* is characterised by the

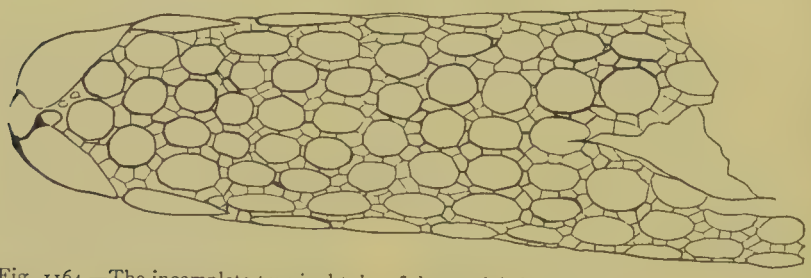


Fig. 1164.—The incomplete terminal tube of the caudal sheath of *Hoplophorus*; from the Pleistocene of South America. One-third natural size.

excessive thickness of its carapace, the scutes of which are tuberculated, and by a caudal sheath composed proximally of several movable rings, but terminating in a long compressed tube ornamented with tubercles, of which some were of very large dimensions, and marked with a radiate sculpture. In *Euryurus* the caudal sheath is of somewhat similar type, but the scutes of the carapace are simply rugose. *Dædicurus*, again, also has the scutes of the carapace rugose, but the terminal tube of the caudal sheath is enlarged into a flattened club-like expansion, covered with coarse tubercles, interspersed with a few larger rough disks having a radiate sculpture; these disks having probably been surmounted, as in *Panochthus*, with horny epidermal spines. The type species attained a length of about 12 feet. Finally, in *Glyptodon* (fig. 1162), with which *Schistopleurum* is probably identical, the scutes of the carapace had a rosette-like sculpture, the peripheral ones being raised into conical prominences, and the caudal sheath, at least in several species, was entirely composed of a series of movable rings, ornamented with large conical tubercles. The humerus was devoid of an entepicondylar foramen; and while there were five complete digits in the manus, those of the pes were reduced to four. *Thoracophorus* differs from all the foregoing in having the scutes of the carapace separated from one another, and thereby approximates

to some of the *Megatheriidæ*, in which there were a number of small ossicles embedded in the dermis of the dorsal region. A similar condition prevails in *Carioderma*, of the Loup-Fork beds of Texas.

Family Myrmecophagidæ.—This family comprises the true Ant-eaters of South America, represented by the genera *Myrmecophaga*, *Tamandua*, and *Cycloturus;* but appears to be unknown in a fossil state. The jaws are entirely destitute of teeth; the body is clothed with hair; the tail is long; there are either four or five digits in the pes; and the third digit of the manus is the longest.

Family Megatheriidæ.—The members of this family are entirely extinct, and are confined to the New World. They comprise a number of very large forms adapted solely for walking on the ground, and showing in their skeletal organisation characters intermediate between the preceding and the following families. Thus, while their vertebræ and limbs are constructed like those of the *Myrmecophagidæ*, their crania and dentition resemble those of the

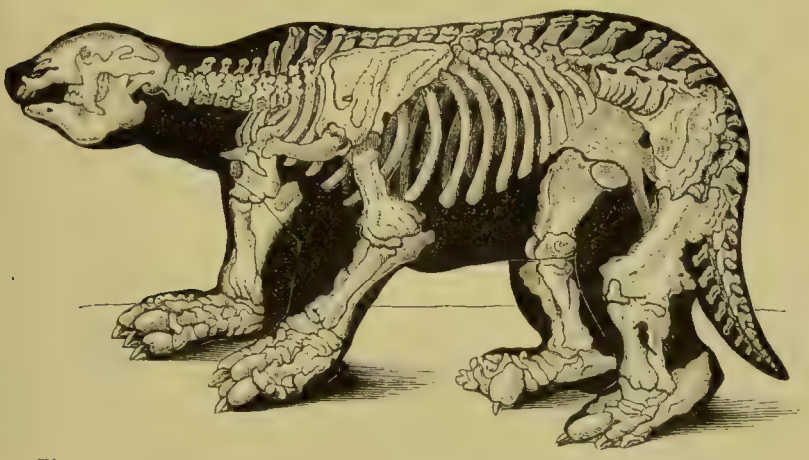


Fig. 1165.—*Megatherium americanum;* from the Pleistocene of South America. Much reduced.

Bradypodidæ. One species of the genus *Scelidotherium* approximates, however, in cranial characters to the former family; and it is probable that the whole three families have originated from a single stock. The number of the teeth is usually $\frac{5}{4}$; and the first and second teeth may be either in apposition or separated by an interval. The femur has no third trochanter; and the under surface of the odontoid process of the axis vertebra presents a peculiar flattened surface for articulation with the atlas. The type genus *Megatherium*[1] is found in the Pleistocene of both South and North

[1] This name should properly be *Megalotherium*, but its antiquity renders it somewhat sacred.

America; the typical *M. americanum* (fig. 1165) of the former region being fully equal in bulk to the largest species of Rhinoceros. The teeth (fig. 1166) consist of square prisms, wearing into transverse ridges through the presence of two vertical plates of hard dentine intercalated between softer dentine and cement; they are similar in

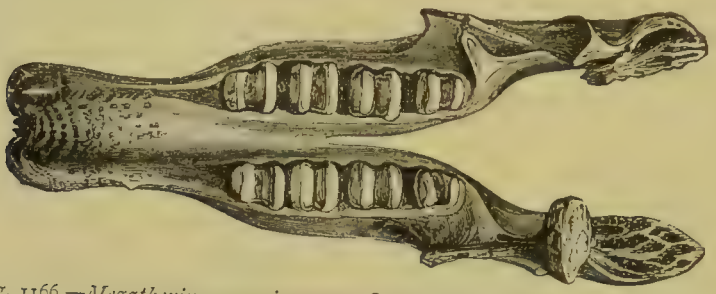


Fig. 1166.—*Megatherium americanum*.—Oral surface of the mandible; from the Pleistocene of Buenos Ayres. Reduced.

structure, and are all in contact. The feet are provided with powerful and huge claws, the third digit in each foot being the longest; and the humerus has no foramen.

There are indications that the snout was prolonged, and more or less flexible; and the tongue was probably prehensile. From the characters of the molar teeth it is certain that the Megathere was purely herbivorous in its habits; and from the enormous size and weight of the body it is equally certain that it could not have imitated its modern allies, the Sloths, in the feat of climbing, back downwards, amongst the trees. It is clear, therefore, that it sought its sustenance upon the ground, and it was originally supposed to have lived upon roots; but by a masterly piece of deductive reasoning, Sir R. Owen showed that this great Ground-sloth lived upon the foliage of trees, like the existing Sloths—but with this difference, that instead of climbing amongst the branches, it actually uprooted the tree bodily. In this *tour de force*, the animal sat upon its huge haunches and mighty tail, as on a tripod, and then grasping the trunk with its powerful arms, either wrenched it up by the roots or broke it short off above the ground. Marvellous as this may seem, it can be shown that every detail in the skeleton of the Megathere accords with the supposition that it obtained its food in this way.

A smaller but allied form from the Pleistocene of South America has been named *Oracanthus*, but since this term is preoccupied by a genus of Palæozoic Fishes, it should be changed. The genus *Scelidotherium* (fig. 1167), which may be taken to include *Platyonyx*, and likewise occurs in the South American Pleistocene, comprises a number of species, and has characters in some respects intermediate between the preceding and the following genera. The teeth in the upper jaw have an irregularly oval section, while those of the mandible are usually subtriangular; the whole of the series are in contact, and their crowns do not wear into ridges. The

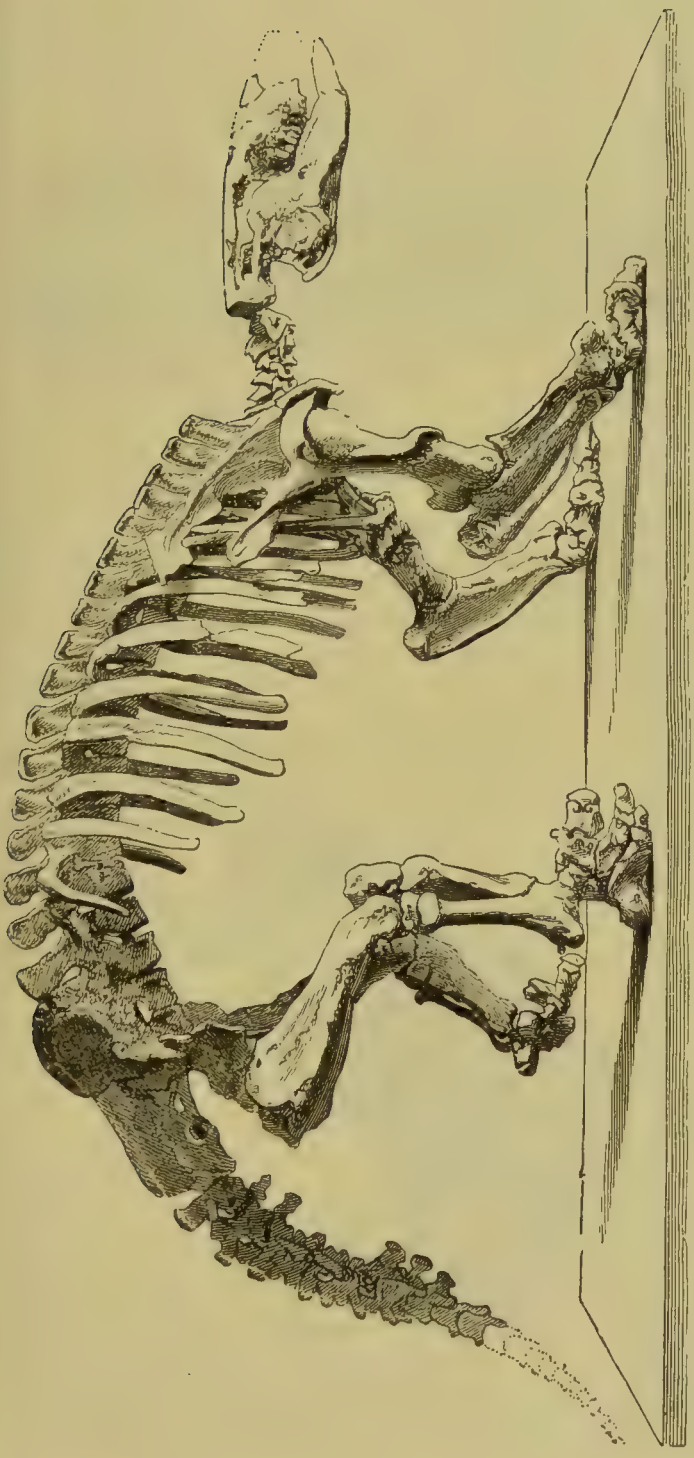


Fig. 1167.—The imperfect skeleton of *Scelidotherium*; from the Pleistocene of South America. One-sixteenth natural size. (After Capellini.)

cranium is low and elongated; and, especially in the type species (fig. 1168), approximates to that of the *Myrmecophagidæ*. The length of the nasals is subject to great variation in the different

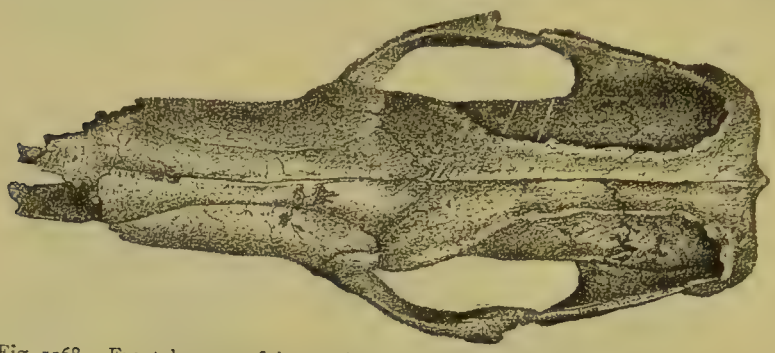


Fig. 1168.—Frontal aspect of the cranium of *Scelidotherium leptocephalum*; from the Pleistocene of South America. One-sixth natural size.

species. The structure of the feet shows a marked deviation from that of *Megatherium*; and the humerus was usually provided with a foramen. The figure of the skeleton is taken from a specimen in the museum at Bologna. The genus *Mylodon* (fig. 1169) com-



Fig. 1169.—*Mylodon robustus*; from the Pleistocene of South America. Much reduced.

prises another group of large Ground-Sloths, which has been split up by some writers into the genera *Lestodon*, *Pseudolestodon*, *Grypotherium*, &c., according to certain not very important differences in

the structure and mode of arrangement of the teeth. In the upper jaw the teeth are usually subtriangular or oval in transverse section, and in typical species there is only a short interval between the first and second tooth in each jaw, and the former is worn horizontally; but in other species there is a considerable interval between the two, and the first is worn obliquely, as in certain Sloths. The humerus has no entepicondylar foramen; and in the shortness of the skull and the characters of the teeth this genus approaches nearer to the modern Sloths than any other member of the family. The best known species is the South American *Mylodon robustus* (fig. 1169), which was smaller than *Megatherium americanum*, its length being about 11 feet; but *M. armatus* (the type of the so-called *Lestodon*), from the same country, is considerably larger. The type species is *M. Harlani*, from the Pleistocene of "Big-bone Lick," in Kentucky, North America; while the Patagonian *M. Darwini* is a very aberrant form, regarded by some writers as generically distinct, and named *Grypotherium*. There are numerous small dermal scutes, which do not articulate with one another. *Megalonyx*, from the Pleistocene of North America, is an allied genus, characterised by the long interval between the large first and the smaller second tooth, and also by the presence of an entepicondylar foramen to the humerus. The type species is *M. Jeffersoni*, from Kentucky and Tennessee; while *M. cubensis*, from the Pleistocene of Cuba, has been separated by some writers under the name of *Megalochnus* (*Myomorphus*). Another form hitherto known as *Cælodon*, but which may be named *Nothrotherium*, on account of the preoccupation of the former term, occurs in the Pleistocene cave-deposits of Brazil, and agrees with *Megalonyx* in the structure of its limbs, but has teeth of the type of those of *Megatherium*, although their number is reduced to $\frac{4}{3}$; the type species considerably exceeded in size the largest Ant-eater of the present day.

The Mammals from the Lower Pliocene and Miocene of North America which have received the names *Moropus* and *Morotherium*, and are regarded by Professor Marsh as forming the type of a distinct family of Edentates—the *Moropodidæ*—probably belong to the Ungulate family *Chalicotheriidæ*.

Family Bradypodidæ.—This family is entirely confined to South America, and now comprises two genera of comparatively small animals which are of exclusively arboreal habits. The body is clothed with coarse hair; the teeth are $\frac{5}{4}$ in number in each jaw, and are of subcylindrical form, with a central axis of soft dentine,

surrounded by a coat of a harder kind of the same substance. The fore-limbs are enormously elongated; and both the manus and pes are furnished with long, curved claws; the number of digits never exceeding three in each foot. The skull (fig. 1170) is short, with a descending maxillary process to the zygoma; and the tail is rudimentary. In *Bradypus* (fig. 1170) the first tooth is equal in size to the second, and is worn horizontally; while the digits are reduced to two. In *Cholœpus*, however, the first tooth is considerably larger than the second, from which it is separated by a much longer interval than in *Bradypus*, and wears obliquely; while there are three digits to each foot. The only known fossil form is from the



Fig. 1170.—Skull of *Bradypus gularis*. Recent. South America. Reduced.

Pleistocene of Argentina, and has been named *Nothropus priscus*; it appears to have been about twice the bulk of *Bradypus didactylus*, and has the first lower tooth separated by a very long interval from the second, although it is of smaller size; the cranium, upper dentition, and feet are unknown.

Order IV. Cetacea.—The Cetacea form, perhaps, the most readily defined and sharply differentiated order in the whole class. Their contour is fish-like, the body being fusiform, and passing imperceptibly into the head without any distinct external neck, and posteriorly gradually tapering to the extremity of the tail, which is furnished with a pair of horizontally-expanded "flukes," formed of dense fibrous tissue covered with skin (fig. 1178). The head is frequently very large, and may be as much as one-third the total length of the animal. The pectoral limbs are reduced to ovoid, paddle-like, organs; and there are no external traces of pelvic limbs. The skin is smooth and without hair; although bristles may be present in the neighbourhood of the mouth, more especially in young individuals. Frequently there is a median dorsal fin (fig. 1178), which however has no bony supports. Both the eye and the external auditory aperture are small; the former having no nictitating membrane, and the latter no pinna. The nostrils open by a single

or double aperture usually near the vertex of the skull. The bones are usually of a spongy nature, and contain a large amount of oil. The cervical region of the vertebral column is always very short; and the seven component elements may be partially or completely fused together, while the odontoid process of the axis when present is short and blunt, and may be entirely wanting. None of the vertebræ unite to form a sacrum. The lumbar and caudal vertebræ are large and numerous, and from the absence of zygapophysial articulations allow of a large amount of motion in the hinder part of the body; the presence of chevron-bones distinguishes the caudals from the lumbars. The terminal epiphyses of the vertebræ do not unite with the centra till the animal is fully adult. The cranium presents peculiar features which it will not be necessary to describe here; although it may be mentioned that the usually small nasals are generally brought up near to the vertex, and that there is a more or less elongated rostrum in advance of the external nares, formed by the premaxilla, maxilla, mesethmoid, and vomer. Clavicles are absent; the scapula and humerus are well developed and freely movable upon one another, but the anterior bones of the limb admit of only a very slight amount of movement. There are usually five digits in the manus (fig. 1171), but these may be reduced to four; the phalangeals are unique among Mammals in exceeding the number of three to a single digit, and also in being furnished with epiphyses. The pelvis is represented by a pair of styliform bones, which are regarded as the ischia; and there are occasionally small ossifications or cartilages representing the aborted bones of the proximal part of the hind limb. Teeth are usually present, but are very variable in number and size. The dentition in existing forms is homœodont and monophyodont, but it was heterodont in the extinct *Zeuglodontidæ* of the Eocene.

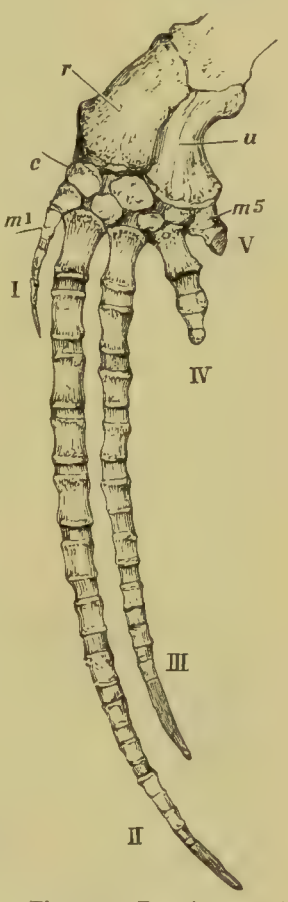


Fig. 1171.—Dorsal aspect of the left pectoral limb of the Black-fish (*Globicephalus melas*). Reduced. *r*, Radius; *u*, Ulna; *c*, Carpus (the letter placed on the scaphoid or radiale); *m1*-*m5*, Metacarpus; I.-V., Phalangeals. (After Flower.)

The Cetacea are not known with certainty before the Eocene, and are most abundant in the later Tertiary periods. The dentition of the Eocene *Zeuglodontidæ* indicates that the order has been

probably derived from Mammals with a heterodont dentition; and Professor Flower comes to the conclusion that it is most probable that their ancestors were allied to the Ungulata; while from the absence of Cetacean remains in the Cretaceous the same authority thinks that the earlier members of the order were inhabitants of freshwater. With the exception of the *Platanistidæ* and some *Delphinidæ*, all existing Cetaceans are of marine or estuarine habits.

In their increased number of phalangeals (hyperphalangism) the Cetacea resemble the Reptilian *Ichthyosauridæ* and *Plesiosauridæ*, and from this circumstance, coupled with their simple type of teeth, it has been argued that they represent the most archaic type of Mammals, and even that they are directly descended from the Ichthyosaurs. As already mentioned there are, however, many practically decisive objections to these views.

For the determination of fossil Cetaceans the solid tympanic and petrosal bones of the internal ear, and less frequently the cranial rostrum, are of especial importance, since these parts are generally well preserved.

Suborder 1. Mystacoceti.—In this suborder, commonly known as the Whalebone Whales, functional teeth are never present, although germs may be developed in the gums; "baleen" or whalebone is always attached to the palate; the tympanic bone (fig. 1172) is anchylosed to the periotic and involuted upon itself; the nasal passages are roofed in by the nasals, the lachrymal is small and distinct from the jugal; and the rami of the mandible are laterally curved, and do not meet in a symphysis.

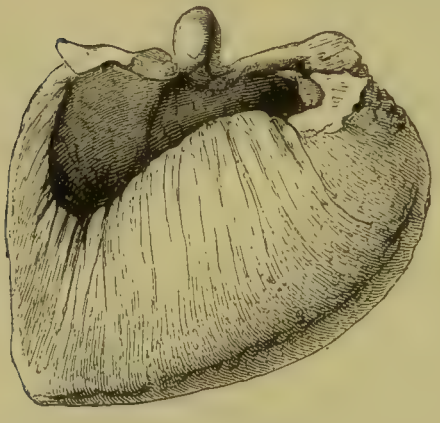


Fig. 1172.—Inner view of the right tympanic of the Greenland Whale (*Balæna mystacetus*). One-third natural size. (After Gray.)

Family Balænidæ. — The only family of this suborder may be divided into the *Balænine* and *Balænopterine* sections. In the first of these there is often no dorsal fin, the tympanic (fig. 1172) has a characteristic flattened and angulated shape, and some or all of the cervical vertebræ are at least usually fused together. Remains of the genus *Balæna* (including *Balænotus* and *Balænula*) occur abundantly in the Pliocene, and especially in the English and Belgian Crags. One of these fossil species (*B. affinis*) is closely allied to the Greenland Whale (fig. 1173); while *B. primigenia* is more nearly related to

the Right Whales of the Southern Seas. *Palæocetus*, which has been regarded by its describer as of Mesozoic age, may be provisionally referred to this section; the type was probably obtained from the Red Crag. In the *Balænopterine* section a dorsal fin is very generally present (whence the name "Finners" applied to many of these



Fig. 1173.—Left lateral view of the skull of the Greenland Whale (*Balæna mystacetus*). Greatly reduced. (After Owen.)

Whales); the cervical vertebræ are free, and thicker than in the *Balænine* section; and the tympanic (fig. 1174) is longer, more inflated, and more rounded than in the latter. The existing genus *Megaptera* (in which may be included the fossil *Burtinopsis*) is abundantly represented in the Pliocene Crags of both England and Belgium. *Balænoptera* also occurs commonly in the same deposits; *B. definita* being apparently nearly allied to the existing *B. sibbaldi*,



Fig. 1174.—Inner view of the right tympanic of a Rorqual (*Balænoptera musculus*). Recent. One-half natural size. (After Gray.)

which attains a length of 80 feet; while *B. emarginata* comes nearer to the living *B. rostrata*, which is seldom more than 30 feet in length, *Cetotherium* (including *Cetotheriophanes*, *Plesiocetus*, and *Plesiocetopsis*) is characterised by the narrowing of the anterior extremity of the tympanic, and is likewise found in the Crags and other Pliocene

beds; while *Herpetocetus* from the same deposits is an allied genus with an egg-shaped tympanic, and a talon to the mandibular condyle, which recalls that of *Physeter*. The names *Amphicetus*, *Idiocetus*, *Isocetus*, *Heterocetus*, and *Mesocetus*, have been applied to Cetaceans from the Belgian Crag, most or all which may apparently be included in *Cetotherium*. Lastly, a vertebra from the Upper Eocene of Hampshire has been referred to *Balænoptera*, but this reference requires confirmation.

Suborder 2. Archæoceti.—This suborder is confined to the Eocene and Lower Miocene, and may be characterised by the long nasals, and the presence of teeth differentiated into groups in both jaws.

Family Zeuglodontidæ.—In the one genus of the only known family the dental formula is $I.\ \frac{3}{3},\ C.\ \frac{1}{1},\ Pm.\ +\ M.\ \frac{5}{5}$. The cutting-teeth are simple and pointed; but the cheek-teeth (fig. 1175)

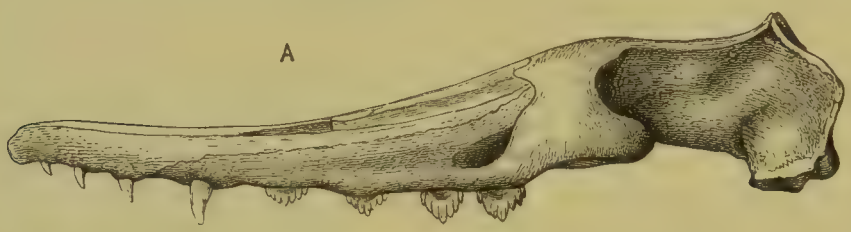




Fig. 1175.—*Zeuglodon cetoides*; from the Middle Eocene of North America. A, Left lateral aspect of cranium, much reduced; B, An upper molar tooth less reduced. (After Gaudry.)

have two distinct roots, and compressed, pointed crowns with denticulated cutting-edges. The cranium is elongated and depressed; the brain-cavity is small; the temporal fossæ and the sagittal crest are large; the cranial rostrum is long, and on the sides largely composed of the premaxillæ; the nasals are long, flat, and narrow; and the external nares are placed more anteriorly than in living Cetaceans. All the cervical vertebræ are free, while those of the lumbar region are unusually elongated; but the nature of the limbs is not known. In their dentition, as well as in the characters of the skull—especially the long nasals and the forward position of the nares—the Zeuglodonts depart less markedly from the general plan of Mammalian structure than any existing members of the order; and it is remarkable that the Mystacoceti show a nearer resemblance in cranial structure to these fossils than is made by the Odontoceti. The one genus *Zeuglodon* is known from the lower Tertiaries of Egypt, England, and North America; the remains of

the typical *Z. cetoides* being extraordinarily abundant in parts of the latter country, where they have been weathered out of a deposit of Middle Eocene age.

Suborder 3. Odontoceti.—All living Cetaceans not included in the Mystacoceti belong to this suborder, which is characterised by the presence of calcified teeth after birth; the functional ones being generally numerous, but sometimes reduced to a single pair (occasionally wanting). Baleen, or whalebone, is invariably absent; the cranium is more or less unsymmetrical; the nasals are reduced to mere bony nodules which do not roof over the narial passages; the lachrymal is either united to the jugal, or of very large size; and the mandibular rami are nearly straight, and meet in a median symphysis. The tympanic is not anchylosed to the periotic, and has not the completely involuted structure found in the Mystacoceti.

Family Physeteridæ.—In this family there are no functional teeth in the upper jaw; and the anterior facet of the periotic for articulation with the tympanic is smooth (fig. 1176), while the posterior tympanic surface of the former bone is broad, with a distinct median ridge. In recent genera some or all of the cervical vertebræ are fused together. This family is divided into the two subfamilies *Physeterinæ* and *Ziphiinæ*. In the former, which comprises the existing Cachalot, or Sperm Whale (*Physeter*), and the Short-nosed Cachalot (*Cogia*), the mandibular teeth are numerous and implanted in a long groove partly divided by imperfect septa. Remains of the gigantic Sperm Whale (*P. macrocephalus*) are found in the English Forest-bed, and also in the Pleistocene of South America; the large teeth have no enamel at their summit. Allied to this genus are *Eucetus* from the English and Belgian Crags, and *Physetodon* from the Pliocene of Australia; while *Physeterula* is a genus founded on a whale from the former deposits, which does not exceed some 20 feet in length. A number of Pliocene and Miocene forms apparently allied to the Cachalot, but with the crowns of the teeth tipped with enamel, have been described as *Balænodon*, *Scaldicetus*, *Hoplocetus*, *Physodon*, and *Ziphioides*; *Hoplocetus* and *Physodon* comprise comparatively small species from the English and Belgian Crags and the French Miocene; while *Ziphioides* is from the Middle Miocene of Baltringen in Würtemberg. In the Ziphiine subfamily, comprising the existing Bottle-nosed (*Hyperöodon*) and Beaked-Whales (*Ziphius* and *Mesoplodon*), all the mandibular teeth, with the exception of one or



Fig. 1176.—The left periotic of *Mesoplodon longirostris*; from the Suffolk Crag.

occasionally two pairs, are rudimentary. *Hyperöodon* is represented in the Crags of England and Belgium. These beds also yield the extinct genus *Choneziphius*, as well as several species belonging to the living genus *Mesoplodon*, which is distinguished from *Choneziphius* by the complete ossification in the adult of all the elements comprising the cranial rostrum. The Crag species of *Mesoplodon* are mainly known by these solid rostra, which in the living species are composed of dense ivory-like bone, and are the most solid bones found in the whole of the Vertebrata. The periotics (fig. 1176) are more rarely found, but are equally characteristic.

Family Platanistidæ.—This family, which is now represented by *Platanista* of the Ganges, and *Inia* and *Pontoporia* of the great rivers of South America, is characterised by the large number of simple teeth in the elongated jaws, and by the length of the mandibular symphysis exceeding half that of the entire mandible. None of the cervical vertebræ are anchylosed together. Remains allied to *Pontoporia* were found by Bravard in the Pleistocene of South America, but these are referred by some authorities to a distinct genus under the name of *Pontistes* or *Palæopontoporia*. The extinct genera *Champsodelphis* and *Schizodelphis*, of the European Pliocene, are usually referred to this family, but the latter approximates to the *Delphinidæ*.

Family Squalodontidæ. — The extinct Squalodonts were formerly classed with the *Zeuglodontidæ*, but the characters of the cranium are essentially Delphinoid, although the teeth are differenti-

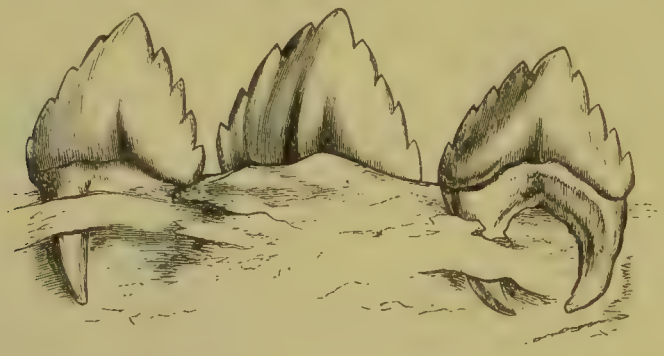


Fig. 1177.—Three lower molars of *Squalodon*; from the Miocene of Europe.

ated into groups as in the former. The type genus *Squalodon* ranges from the Middle Miocene to the Pleistocene of Europe, and is also found in the Tertiaries of North America, New Zealand, and Australia. The teeth may be arranged as $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{4}$, $M.\frac{7}{7}$; the premolars are simple, but the true molars (fig. 1177) have double roots, and crowns very like those of *Zeuglodon*, although

distinguished by the denticulations being more developed on the posterior than on the anterior border. The so-called *Rhizoprion* is merely a species of this genus.

Family Delphinidæ.—In this, the last family of the Cetacea, the teeth are simple, and usually numerous in both jaws; and the length of the mandibular symphysis may be very small, and never exceeds one-third of that of the entire ramus. The periotics (fig. 1179), which are frequently found in a fossil condition, are readily distinguished from those of the *Physeteridæ*, by having the anterior facet which articulates with the tympanic marked by a

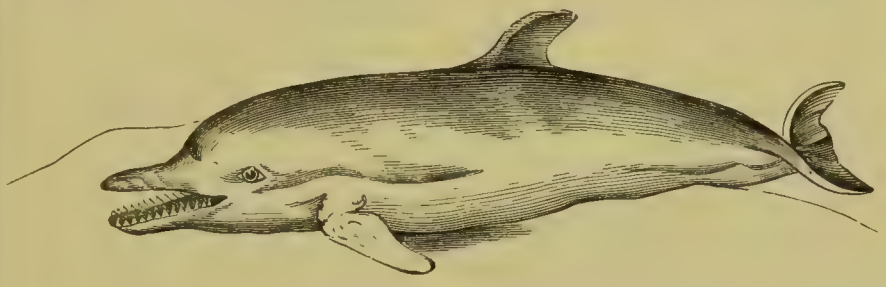


Fig. 1178.—The common Dolphin (*Delphinus delphis*). Reduced.

number of grooves, as well as by the narrowness of the posterior half of their tympanic aspect. This family comprises all the Cetaceans commonly known as Porpoises, Grampuses, Killers, and Dolphins. Remains of the Narwhal (*Monodon monoceros*) are found in the Norfolk Forest-bed and the Pleistocene of Alaska. The genus *Delphinapterus*, now represented by the "White Whale," occurs in the Lower Pliocene of Tuscany, as well as in the Pliocene and Miocene of other parts of Europe. An extinct species of "Killer-Whale" (*Orca*) is found in both the Italian and English Pliocene. The existing *Globicephalus melas*, or "Black-fish," has left its remains in the superficial deposits of Essex; while the extinct *G. uncidens* occurs in the Suffolk Crags. A left periotic of the latter species is represented in fig. 1179, in order to show the features characteristic of this family. The existing *Pseudorca crassidens* was originally described from a subfossil cranium found in the fens of Lincolnshire. Of the smaller Dolphins it is probable that the genera *Tursiops*, *Lagenorhynchus*, and *Delphinus* (as now restricted) are all represented in the Pliocene of Europe. *Eurhinodelphis* is a long-snouted genus from the Pliocene of Belgium and Italy, which is

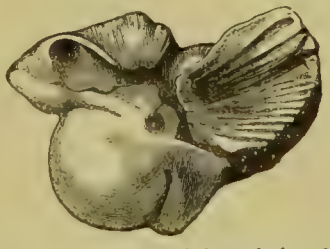


Fig. 1179.—The left periotic of *Globicephalus uncidens*; from the Coralline Crag of Suffolk.

probably nearly related to the existing *Steno*. Delphinoid remains from the Miocene of North America have been described by Professors Leidy and Cope under the names of *Priscodelphinus*, *Tetrosphys*, *Zarhachis*, *Lophocetus*, *Rhabdosteus*, *Ixacanthus*, *Anoplonassa*,

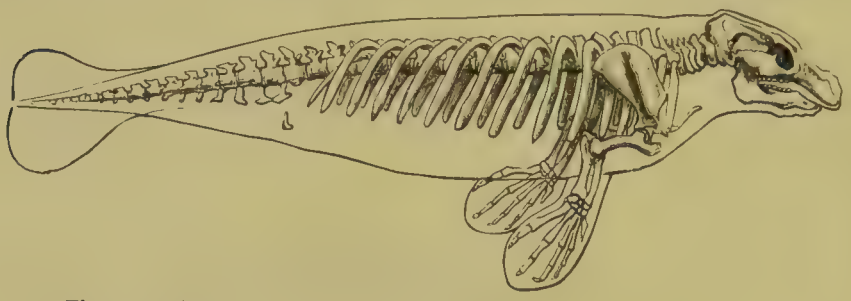


Fig. 1180.—Skeleton of the Manatee (*Manatus australis*). Greatly reduced.

and *Orycterocetus;* but further information is required as to the affinity of these forms and their right to generic distinction.

Order V. Sirenia.—The Sirenia, now represented only by the Manatees and Dugongs, agree with the Cetacea in their adaptation for a purely aquatic life, and accordingly present a strong general resemblance in their external contour to the members of that order. The head is, however, of normal relative size; the tail has a hori-

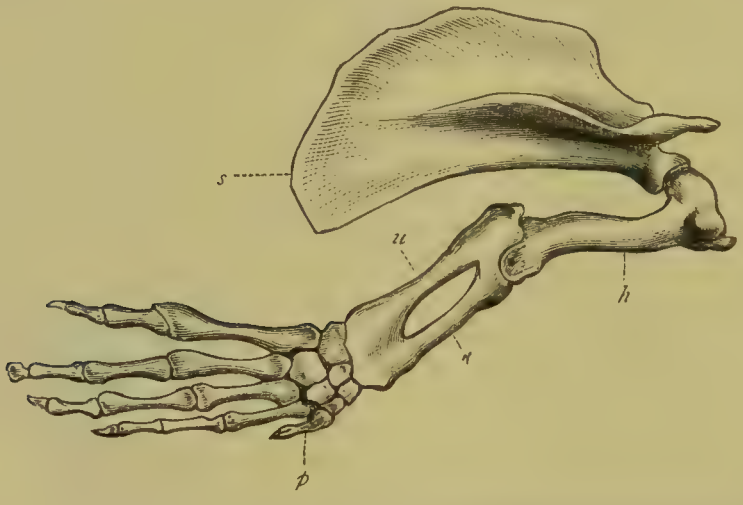


Fig. 1181.—Dorsal view of the right pectoral limb of *Manatus australis*. Much reduced. *s*, Scapula; *h*, Humerus; *r*, Radius; *u*, Ulna; *p*, Pollex.

zontal membranous expansion; the pectoral limbs, although modified into paddles (fig. 1181), retain the normal number of phalangeals; all external traces of the pelvic limbs are wanting; and the surface of the body is either naked or covered with sparse bristles. The lips are fleshy; the nostrils placed near the extremity of the muzzle

(fig. 1180); the eyes minute; and the small ear has no external pinna. The bones of the skeleton are extremely dense and solid; the cervical vertebræ may be reduced to six, but are never anchylosed together; and the axis has a well-developed odontoid process. The vertebræ have no epiphyses; and none of them unite to form a sacrum. Large chevron-bones are present. Clavicles are wanting; and no recent forms show any trace of the femur, although a styliform rudiment of this bone is found in the extinct *Halitherium*. The two bones of the forearm in the existing genera (fig. 1181) are subequal in size, and frequently anchylosed together. In recent forms the skull (fig. 1182) is remarkable for the upward direction

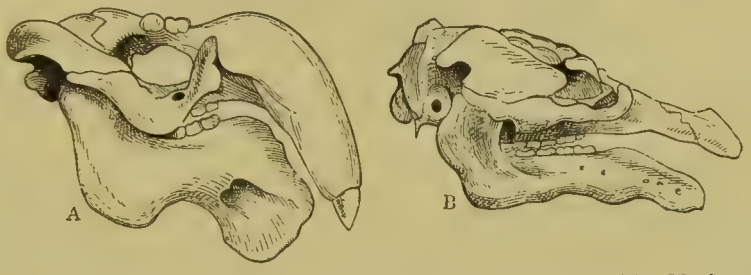


Fig. 1182.—Right lateral view of the skulls of *Halicore* (A) and *Manatus* (B). Much reduced.

of the narial aperture, and for the absence or rudimental condition of the nasals. The teeth can only be differentiated in the living genera into incisors and cheek-teeth, which are separated from one another by a long interval; but in one fossil genus there is a more complete dental series; while in *Rhytina* these organs were totally wanting. In the existing genera the dentition is monophyodont, but milk-molars occur in *Halitherium*. This order is known from the Eocene upwards, but appears to have been steadily dying out to the present period. The fossil forms, although decidedly more generalised than their living representatives, do not at present afford any clear indication as to the origin of the order.

Family Halicoridæ.—In this family the one existing genus *Halicore* (Dugongs) has the deflected premaxillæ (fig. 1182, A) furnished with a pair of large tusk-like incisors; and there are also four pairs of functionless germs of cutting-teeth in the similarly deflected mandibular symphysis. Five or six cheek-teeth are developed in each jaw, which are usually cylindrical, and all grow from persistent pulps, and are not coated with enamel. The Dugongs inhabit the coasts of the Red Sea and the Indian Ocean. *Prohalicore*, from the Pliocene of France, is regarded as nearly allied to the existing genus. The only other form which has been referred to this family is known by a molar from the Tertiary of California, which has been described by Professor Marsh under the name of

Desmotylus. Further information is, however, required before this reference can be definitely accepted.

Family Halitheriidæ.—The fossil forms constituting the *Halitheriidæ* are characterised by the presence of upper incisors; by the cheek-teeth being coated with enamel, like those of the *Manatidæ*; and by the retention, in at least some cases, of a milk dentition.



Fig. 1183.—Grinding surface of the penultimate and last right lower molars of *Halitherium fossile*; from the European Miocene.

In the type genus *Halitherium* (which may be taken to include *Halianassa*, *Pugmeodon*, and *Felsinotherium*) there is a pair of tusk-like upper incisors, and either five or six cheek-teeth in each jaw; small nasals are present in at least some of the species; the premaxillæ and mandibular symphysis are bent downwards; there is a descending plate at the angle of the mandible; and a small rod-like ossification represents the femur. The molars (fig. 1183) have a pattern on their grinding surface resembling that of *Hippopotamus*.

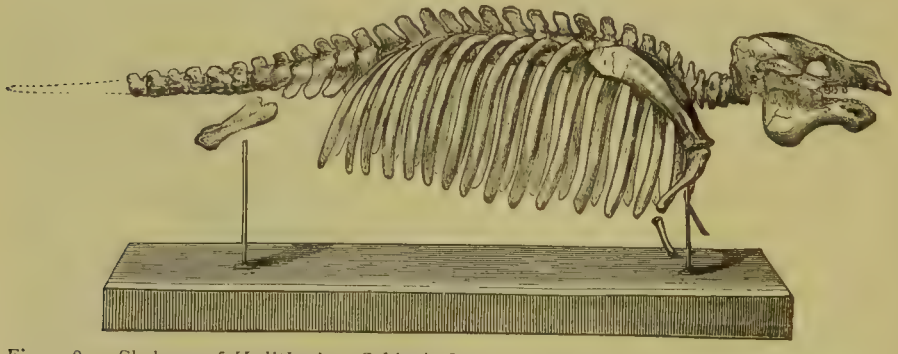


Fig. 1184.—Skeleton of *Halitherium Schinzi*; from the Lower Miocene of Hessen-Darmstadt. Much reduced.[1]

This genus ranges from the Lower Miocene (Middle Oligocene) to the Lower Pliocene of Europe; and remains of *H. Schinzi* (fig. 1184) are especially abundant in the Lower Miocene sands of certain districts of Hessen-Darmstadt. *Prorastomus*, from Tertiary strata in the West Indies, is a generalised form apparently

[1] In this figure the deflection of the premaxillæ is omitted.

allied to *Halitherium*, but with a fuller dentition, and without the marked deflection of the extremities of the jaws. The dentition is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.+M.\frac{7 \text{ or } 8}{7 \text{ or } 8}$; the upper incisors are not tusk-like; and the cheek-teeth have simple transverse ridges somewhat like those of the Ungulate genera *Dinotherium* and *Listriodon*. *Eotherium* is definitely known by a cast of the brain-cavity from the Eocene of Egypt, but teeth from the same deposits described under the name of *Manatus* may perhaps belong to it; its affinities cannot yet be properly determined. Probably allied to *Halitherium* is *Crassitherium* from the Pliocene of Belgium; while *Dioplotherium* from the Miocene of South Carolina is regarded as intermediate between *Halicore* and *Halitherium*.

Family Rhytinidæ.—The *Rhytinidæ* are known only by the huge *Rhytina gigas*, or Steller's Sea-Cow, which was formerly very abundant on Behring and Copper Islands in the North Pacific, but is commonly supposed to have been exterminated about 1768, although a few individuals may have lingered on to a considerably later date. The Rhytina attained a length of from 20 to 25 feet, and is characterised by the entire absence of teeth, their function being supplied by horny plates (cornules) on the palate. The head is very small in proportion to the length of the body; and has the premaxillæ and mandibular symphysis moderately deflected. The skin was naked, and covered with a rugged epidermis resembling the bark of a tree. Nearly entire skeletons have been obtained from the peat of Behring Island.

Family Manatidæ.—In *Manatus*, the only known representative of this family, the premaxillæ and mandibular symphysis (fig. 1182, B) are not deflected, and there are no functional incisors. The cervical vertebræ are reduced to six; the cheek-teeth, which are coated with enamel and carry two transverse ridges, may be as many as eleven in each jaw, although it is seldom that more than six are present at any one time. The Manatees are inhabitants of the mouths and estuaries of the great rivers discharging into the two sides of the Atlantic. No fossil forms are known which can be referred with certainty to this family, although the type generic name has been applied to certain teeth from the Eocene of Egypt already mentioned.

As Sirenians of uncertain affinity may be mentioned *Chronozoum* from the later Tertiary of New South Wales; *Hemicaulodon* from the Eocene of Shark River; *Pachyacanthus* from the Miocene of Vienna; and *Trachytherium* (with which *Rhytiodus* may perhaps be identical) from that of France.

CHAPTER LXI.

CLASS MAMMALIA—continued.

Order Ungulata.

Order VI. Ungulata.—The Ungulata, or Hoofed Mammals, constitute the largest and one of the most important orders into which the class is divided; all the included groups being so connected together as to preclude their division into well-defined separate orders. This order comprises at least seven suborders, of which three are totally extinct, while all the others, with the exception of the Hyracoidea, have lost a large number of family types at the present day. The two first suborders—Artiodactyla and Perissodactyla—present several features in common, and are accordingly brigaded together by some authorities under the names of Ungulata Vera, Clinodactyla, or Diplarthra; while all the others are included in a second division under the name of Subungulata.

All the members of this order are adapted for a terrestrial life, and in the main for a vegetable diet, although a few are more or less omnivorous. Their dentition is heterodont and diphyodont, and the milk-set is well developed, and not changed till late in life; and in the Perissodactyla alone among Mammals do we find certain instances where the whole four premolars are preceded by milk-teeth. The cheek-teeth of the more typical forms have broad crowns, with either tuberculated or ridged surfaces; and their crowns are very frequently interpenetrated by deep folds of enamel, which produce a complicated pattern on their worn surfaces. Except in *Typotherium*, clavicles are always wanting. The toes, with the exception of *Chalicotherium*, are provided either with blunt, broad nails, or with hoofs more or less completely encasing the terminal phalangeals. The feet of existing types are digitigrade, and the number of the toes varies from five to one. In all existing forms the humerus has no entepicondylar foramen. The scaphoid and

lunar bones of the carpus are always distinct; but the radius and ulna may unite.

In the great majority of instances the cheek-teeth are rooted, and in the suborders Artiodactyla, Perissodactyla, and Proboscidea, which comprise the most specialised members of the order, a gradual increase in the height of the crowns of these teeth may be traced from the generalised to the specialised genera. Those teeth in which the crowns are low, and their whole structure is visible from the grinding surface, being known as *brachydont* (compare fig. 1195); while those with high crowns, in which the bases of the enamel-folds are invisible from the grinding surface, are termed *hypsodont* (fig. 1220). The change from a brachydont to a hypsodont dentition is accompanied by the production of a nearly flat and horizontal grinding surface in the cheek-teeth, in place of a more or less strongly ridged one; the more specialised type being adapted for a perfect grinding action of the upper against the lower teeth, while in the more generalised type the action is to a great extent a snapping one. Examples of the former type are shown by the Horse and Ox, and of the latter by the Pig and Hyrax. Hypsodontism is not confined to this order, as will be noticed in the sequel.

Some remarks on the probable origin of the order are made below under the head of the Condylarthra. In the specialised forms there is very often a tendency to a suppression of the anterior teeth, more especially in the lower jaw.

Suborder 1. Artiodactyla. — This and the next suborder present certain structural modifications of the extremities, by which they are distinguished from the remaining five suborders, and on which account, as already mentioned, they are grouped together by some writers under the name of Ungulata Vera, or Diplarthra. Thus the feet are never plantigrade, and the number of functional digits does not exceed four. In the carpus (fig. 1185) the scaphoid is supported by and largely articulates with the magnum; while the latter (together with the unciform) supports the lunar, and has no connection with the cuneiform. In the tarsus the cuboid extends inwardly to articulate with the astragalus, which is deeply grooved (fig. 1186). All the component bones of both the carpus and tarsus strongly interlock, which makes the structure of these joints more complex than in the other suborders. Finally, the jugal forms the anterior part of the zygomatic arch (fig. 1187), and the brain is of relatively large size and complex structure.

This suborder, so far as at present known, is distinguished from the Perissodactyla by the distal surface of the astragalus (fig. 1186) being ginglymoid, by the third and fourth digits (fig. 1185) being equal in size, and arranged symmetrically on either side of a line drawn between them; by the absence of a third trochanter

to the femur; and by the articulation of the fibula with the calcaneum. In all existing forms the number of the dorso-lumbar

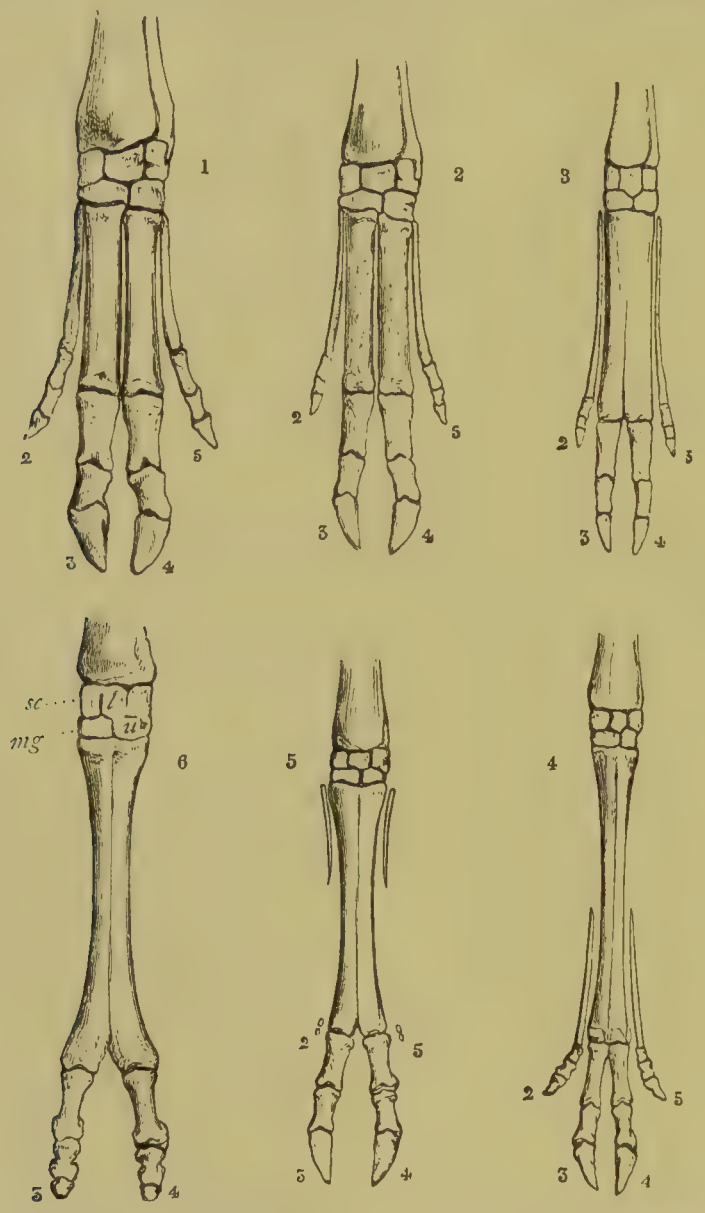


Fig. 1185.—Left manus of (1) Pig (*Sus*), (2) *Hyomoschus*, (3) Chevrotain (*Tragulus*), (4) Roebuck (*Capreolus*), (5) Sheep (*Ovis*), and (6) Camel (*Camelus*). In the carpus the middle bone in the upper row is the lunar, the left the scaphoid, and the right the cuneiform; in the second row the left bone is the magnum, and the right the unciform. Reduced. (After Dawkins and Oakley.)

vertebræ is nineteen; and the nasals are not expanded posteriorly. In the dentition the first tooth of the cheek series never has a deciduous predecessor. The upper premolars are very generally

more simple in structure than the true molars; while the last lower true molar nearly always has a third lobe, the same feature being repeated in the last lower tooth of the milk series.

In the Pecora the pelvis (fig. 1128 *bis*) is characterised by the great length of the ilia, which are not much expanded; but in the Hippopotamus these bones are shorter and more expanded, and thus approximate to those of the Perissodactyla. The symphysis of the ischia and pubes is much elongated. The true molars in the upper jaw carry either four or five main columns; in the less specialised forms such as the Pigs (figs. 1194, 1195), such columns in both upper and lower molars form low subconical tubercles, when the dentition is termed *bunodont;* but in others, such as *Eporeodon* (fig. 1201) and the Ruminants (fig. 1220), the outer pair of columns becomes transversely flattened, and the inner pair crescent-shaped, and the dentition is then termed *selenodont*. In the lower molars of the latter type of dentition it is the inner columns that become flattened, while the outer ones assume a crescent shape. There is, however, a complete passage from the one type to the other; the most specialised forms with a hypso-selenodont dentition being of comparatively recent origin. The existing members of this suborder are divided into the sections Suina (Pigs and Hippopotamus), Tylopoda (Camels), Tragulina (Chevrotains), and Pecora (typical Ruminants); but since such divisions will not hold good for the fossil forms, it will be convenient merely to divide the suborder into families.



Fig. 1186.—Left astragalus of a Ruminant Artiodactyle (*Bos*). Reduced.

It should, moreover, be observed that it is by no means certain that all the above-mentioned characters will apply to some of the less known earlier members of the suborder, since some of these included in the *Anoplotheriidæ* present certain remote indications of affinity with the Perissodactyla.

The advance from a bunodont to a hypso-selenodont dentition is accompanied in this suborder by a tendency in the second and third metapodials to coalesce into a *cannon-bone*, and also by a change in the form of the odontoid process of the axis vertebra from a peg-like projection to a spout-like demicylinder. The earliest form which has been referred to this suborder is the small *Pantolestes*, from the Lower Eocene of the United States. This genus is still very imper-

fectly known; but Professor Cope, who makes it the type of a distinct family, states that it has tritubercular upper molars, and four digits in the pes, and looks upon it as the ancestral type of the Camels. Dr Schlosser is, however, not satisfied that the teeth are



Fig. 1187.—Left aspect of the Hippopotamus (*H. amphibius*). Much reduced. (After Giebel.)

really tritubercular, and suggests that it may indicate a transitional type between the Artiodactyla and the Condylarthra.

Family Hippopotamidæ.—This family contains the single Old World genus *Hippopotamus*, now represented by two species of



Fig. 1188.—Left manus of *Hippopotamus amphibius*. Reduced. (After Cuvier.)



Fig. 1189.—Left upper true molar of *Hippopotamus amphibius*. Two-thirds natural size.

bulky animals, which spend a large proportion of their time in the waters of lakes and rivers. In the skull (fig. 1187) the angle of the mandible has a descending flange; the facial portion is much elon-

gated; and the orbits are tubular and very prominent. The dental formula is *I.* $\frac{(2-3)}{(1-3)}$, *C.* $\frac{1}{1}$, *Pm.* $\frac{4}{4}$, *M.* $\frac{3}{3}$. The cheek-teeth are bunodont in structure; the true molars (fig. 1189) having four columns, which present trefoil-shaped dentine surfaces when worn; the premolars are simpler. The upper incisors are short and vertical (fig. 1187), but those of the lower jaw are procumbent, and may be very large (fig. 1191). The canines of the upper jaw are curved upwards like those of pigs, while the lower ones are of enormous size, and have their extremities obliquely worn to a cutting-

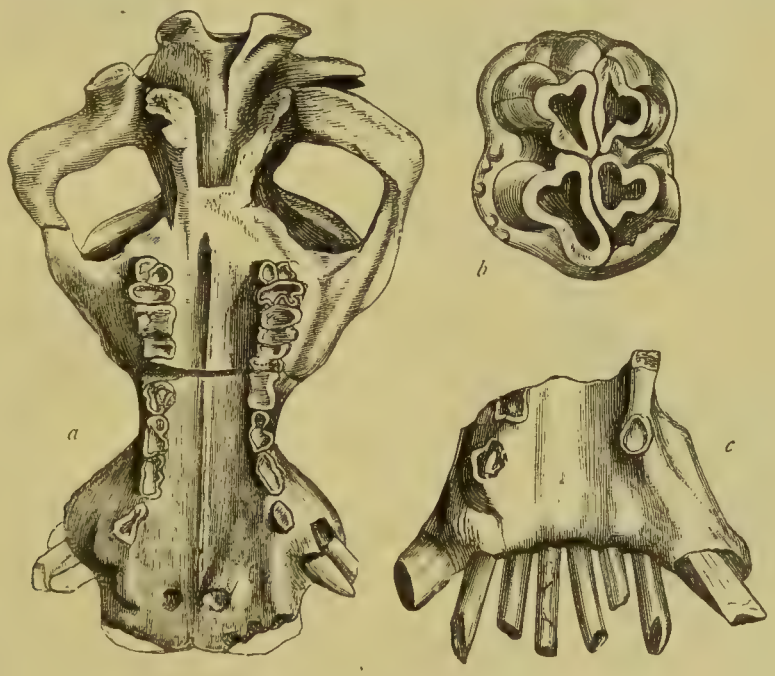


Fig. 1190. —*Hippopotamus sivalensis;* from the Pliocene of the Siwalik hills. *a*, Palatal view of cranium; *b*, Third right upper true molar; *c*, Symphysis of mandible. Reduced.

edge by biting against the outer surfaces of those of the upper jaw. The feet (fig. 1188) are short and massive, and furnished with four digits, of which the terminal phalangeals bear nail-like hoofs. The skin is nearly naked and of great thickness; while the ears and eyes are very small, and the tail is short.

In the more generalised forms like *H. sivalensis* (fig. 1190), of the Pliocene of the Siwalik Hills of India, there are three pairs of incisors in both jaws, all of which are of subequal size. This hexaprotodont group is represented in the Pliocene of Burma by *H. iravaticus*, and in that of Algiers by *H. bonariensis;* while its latest member is *H. namadicus*, of the Pleistocene of the Narbada Valley, in India. In the latter deposits

also occurs *H. palæindicus*, in which the second lower incisor is very minute, and perhaps disappears in the adult; while in the existing *H. amphibius* of Africa, which is found fossil in Europe from the Upper Pliocene of the Val d'Arno to the late Pleistocene, there are only two pairs of incisors in each jaw, the innermost pair in the mandible being of enormous dimensions (fig. 1191). It is evident from the condition prevailing in *H. palæindicus* that it is the second pair of incisors which is missing in the existing species. Allied to, but smaller than the latter, are *H. Pentlandi* and *H. minutus*, whose remains are found in enormous quantities in the caves of Italy and the Mediterranean islands. Finally,



Fig. 1191.—Mandible of *Hippopotamus amphibius*. Reduced.

in the small *H. liberiensis*, now living in West Africa, the number of lower incisors is reduced to a single pair. The resemblance of the mandible of *Hippopotamus* to that of the *Anthracotheriidæ* suggests that both are derived from a common ancestor.

Family Suidæ.—This family may be taken to include both the existing *Dicotylidæ* and *Phacochœridæ* and the extinct *Listriodontidæ*, since fossil forms indicate a close connection between all these types. The cheek-teeth are typically bunodont and brachydont, the upper true molars carrying four main columns, which may be either simple (fig. 1195) or of extreme complexity (*Hippohyus*), but which do not wear into distinct trefoils. Their outer and inner columns may, however, coalesce into transverse ridges (fig. 1193). The skull (fig. 1192) has a more or less elevated supraoccipital region, from which the profile slopes away to the muzzle, the nasals being frequently much elongated; while the mandible has no descending flange at the angle. The canines are frequently large and tusk-like (fig. 1192), the superior ones being curved upwards, and the lower ones biting against a facet on the outer surface of the upper ones; but in many of the earlier forms, and in the recent Peccaries, the

development of these teeth is much less marked. The digits are usually four in number, but in the existing forms (fig. 1185) only



Fig. 1192.—Right lateral aspect of the skull of the Wild-boar (*Sus scrofa*). Reduced. (After Gray.)

the two middle ones touch the ground. The dental formula is very generally the typical one.

The extinct genus *Listriodon* differs from all the other members of the family in that the true molars (fig. 1193) carry a pair of simple transverse ridges. The dental formula is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{3}{3}$, $M.\frac{3}{3}$; the canines form large tusks; the last upper premolar is simpler than the true molars; and the anterior premolars are relatively wide. The skull is essentially that of a Pig. Remains of *Listriodon* occur in the Middle Miocene of the Continent (where they have been described under the names of *Lophiochœrus* and *Tapirotherium*), and also in the Pliocene Siwaliks of the Punjab and Sind. The molars present the same relation to those of *Sus* as is borne by the molars of *Dinotherium* to those of many species of *Mastodon*.



Fig. 1193.—The second left upper true molar of *Listriodon splendens*; from the Middle Miocene of France.

Leaving this aberrant type, we may turn to the typical genus *Sus*, in which the normal dental formula is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{4}$, $M.\frac{3}{3}$, although the first premolar is absent in some fossil species, and also in the African *Potamochœrus*, which cannot be palæontologically separated. The canines are developed into tusks (fig. 1192), although they are small in the earlier species. The crowns of the upper true molars are oblong, and both the upper and lower last true molars (fig. 1194) have a third lobe, although its degree

of development varies greatly; and these teeth do not come into use until the first molar has been well worn. The anterior premolars are compressed, and there is no diastema between the first and the second. The upper premolars are simpler than the true molars, and there is considerable difference in the number of accessory tubercles developed in the latter; those species in which these are most numerous showing a more complex pattern on the worn crowns. The molars of some of the earlier forms approximate to those of *Hyotherium*.



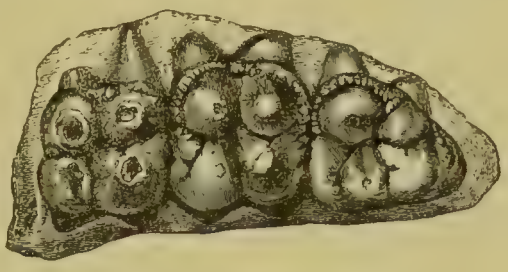
Fig. 1194.—The third right lower true molar of *Sus cristatus*; India. *a*, *d*, Middle columns of talon.

The species with the most complicated molar structure are *S. Falconeri* of the Pliocene of the Siwalik Hills, *S. phacochœroides* of the Pliocene of Algeria, *S. karnuliensis* of the Pleistocene caves of Madras, and the living Indian *S. cristatus* (fig. 1194), which is also found fossil in the same caves; the last lower true molar of the first-named species making a decided approach to that of *Phacochœrus*. In the European Wild-boar, which is found fossil as low down as the Norfolk Forest-bed, the hind lobe of the last molar is of moderate complexity. *S. titan*, and *S. giganteus* of the Siwalik Hills of India, together with *S. antiquus*, *S. erymanthius*, and *S. major* of the Lower Pliocene of Europe, are large species with comparatively simple molars; the first being the largest known species, and fully equal in size to a Tapir. *S. hysudricus* of the Siwalik Hills, *S. palæochœrus* of the Lower Pliocene of Eppelsheim, and *S. chœroides*, which has been recorded from France and the Middle Miocene of Tuscany, are small species with simple molars like those of the living *S. andamanensis*, to which they may be allied. *S. arvernensis* of the Upper Pliocene of France is closely related to the living African *S.* (*Potamochœrus*) *africanus*; while in the small *S. punjabiensis* of the Pliocene of north-western India we probably have the direct ancestor of the Pigmy-hog (*S. salvanius*) of the terai-lands of Nipal. No representatives of the genus occur in America; and *S. chœroides* seems to be the earliest species.

Here it will be convenient to notice the African Wart-hogs (*Phacochœrus*) which appear to be related to some of the specialised fossil species of *Sus*. The dental formula is $I.\ \frac{1}{(2-3)}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{2}{3}$, $M.\ \frac{3}{3}$, but the whole of the teeth with the exception of the canines and the last true molars may be lost in the adult, thus presenting a very remarkable instance of extreme specialisation. The last true molar is a very peculiar tooth, consisting of a great number of tall agglomerated columns, or denticules; but a marked approach to this structure is presented in some of the species of *Sus* from the

Pliocene of Algeria and India. Remains of *Phacochœrus* occur in superficial deposits in Africa. The last molar of this genus compared with that of *Hyotherium* presents a difference analogous to that between the corresponding teeth of *Mastodon* and the Mammoth.

We may now revert to the consideration of more generalised types. The most important is *Hyotherium* (in which may be included *Palæochœrus* and *Chœromorus*) which presents characters connecting it with *Dicotyles*, *Sus*, and *Chœropotamus*, and may have been the ancestor of the first two of these genera. The upper true molars (fig. 1195) have low, square crowns, with a rudimentary fifth column, which is fully developed in *Chœropotamus;* and the last true molar comes into use before the first is worn. In the third upper true molar there is no third lobe, and this lobe is small in the corresponding lower tooth; while occasionally the last upper premolar has only a single outer column, as in *Chœropotamus*. The canines are scarcely larger than the incisors; are oval in section, and the lower one is not received into a notch in the upper jaw. The lateral metapodials are stouter than in modern pigs. In Europe this genus ranges from the Quercy Phosphorites to the Middle Miocene of the Continent; while in India it occurs in the Lower Siwaliks of Sind, and also in Perim Island (fig. 1195); the American forms which have been referred to this genus are regarded by Professor Cope as distinct. *Hippohyus*, of the Indian Siwaliks, appears to be an allied but specialised form, in which the crowns of the molars are much taller, and have lateral infoldings of the enamel, whereby an extremely complex pattern is produced on their worn surfaces. *Sanitherium* of the Siwaliks must be placed with this group; while *Doliochœrus* of the Quercy Phosphorites is apparently allied to *Hyotherium*, although it may also have affinity with *Cebochœrus*. The genus *Babirusa*, of Celebes, is unknown in a fossil state.



m. 1. *m.* 2. *m.* 3.

Fig. 1195.—The left upper true molars of *Hyotherium perimense;* from the Pliocene of India.

In the John Day Miocene of the United States there occur pig-like animals apparently connecting *Hyotherium* with the existing Peccaries, most of which may be included in the genus *Chœnohyus*. These forms agree with *Hyotherium* in having the fourth upper premolar simpler than the true molars, but have the lower canine with

a triangular section, and received into a notch in the upper jaw, as in the Peccaries. The typical forms have only three premolars, but in others, which it has been proposed to separate generically as *Bothrolabis*, there are four of these teeth. Allied, or probably identical forms have been described as *Thinohyus* and *Perchœrus*, the former having four premolars. The existing South American genus *Dicotyles* includes the well-known Peccaries, and has the dental formula $I.\frac{2}{3}$, $C.\frac{1}{1}$, $Pm.\frac{3}{3}$, $M.\frac{3}{3}$. The structure of the small canines has been already mentioned; the last upper premolar has four columns like the true molars (fig. 1196); while the third upper

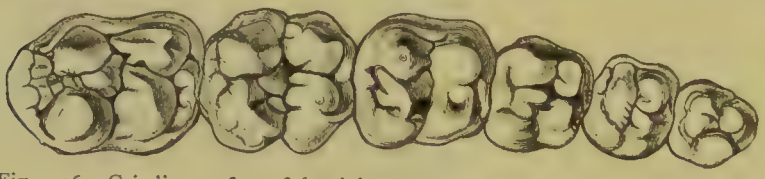


Fig. 1196.—Grinding surface of the right upper cheek-teeth of a Peccary (*Dicotyles labiatus*). (After Giebel.)

true molar, which comes into use before the first is worn, has no distinct third lobe. In the pes the phalangeals of the fifth digit are aborted. Remains of two existing and one much larger extinct species of this specialised genus are found in the Pleistocene deposits of the Brazilian caves; while large Peccaries also occur in the Pliocene of the United States and the Pleistocene of Mexico, which have been described as *Platygonus*, but may be included in the type genus, although they have rather simpler premolars.

Family Chœropotamidæ.—The true molars of this extinct family are intermediate in structure between those of the *Suidæ* and *Anthracotheriidæ;* having in the upper jaw very broad and short crowns, which carry five columns arranged as in the latter family. The premolars, although somewhat compressed, are not secant, and may be of very large size. In the two best known European genera there is a diastema between the first and second upper premolars. The mandible has no descending flange at the angle.

One of the most pig-like members of this family is the genus *Cebochœrus*, comprising animals of the size of *Hyotherium*, which have been considered by some as allied to the *Lemuridæ*, although there is little doubt that their true relationships are with the present group. They apparently possessed the full typical number of teeth, which (especially in the lower jaw) present a great resemblance to those of *Hyotherium;* and it is highly probable that they are closely related to the ancestor of that genus. *Cebochœrus* is represented by several species in the Upper Eocene of France; but the form re-

corded from the Middle Miocene of Bavaria may be generically distinct. Allied to this genus are *Hemichœrus* of the Quercy Phosphorites, and *Leptochœrus* of the North American Miocene, in which the premolars have a very simple structure. All these forms, together with the following genus, are placed by some writers with the *Suidæ*. The type genus *Chœropotamus* occurs in the Upper Eocene of France and England, and has been erroneously stated also to occur in the Miocene of Bavaria. The upper true molars resemble those of certain species of *Anthracotherium*, but have shorter crowns, with a less approach to a selenodont structure. There is a third lobe to the last lower true molar, and the dental formula is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{3}$, $M.\frac{3}{3}$. The feet are unknown, but it is probable that they were furnished with four digits. The type species *C. gypsorum* of the Paris gypsum, was an animal of the size of a large Pig; and it is probable that this genus is a survivor of a form which was the common ancestor of both the *Suidæ* and the *Anthracotheriidæ*. *Elotherium*, which has been also described under the names of *Entelodon*, *Archæotherium*, *Oltinotherium*, and *Pelonax*, is a larger form allied in many dental characters to *Chœropotamus;* and is one of the very few members of this suborder in which the last lower true molar has no third lobe. The premolars are relatively large and simple; the canines recall those of some of the Carnivora; and the functional digits of the feet are reduced to two. The dental formula is the typical one; and the genus is placed by some writers in the *Anthracotheriidæ*. Its remains are found in the Upper Eocene Phosphorites of Quercy, in the Lower Miocene of Ronzon, in France, and of Hempstead in the Isle of Wight, and also in the Miocene of North America. Apparently allied to this genus is *Tetraconodon* of the Pliocene of the Indian Siwalik Hills, in which the last lower molar has a third lobe, and the conical premolars are of enormous size. In this neighbourhood must probably also be classed the remarkable North American Eocene genus *Achænodon* (probably identical with *Parahyus*) which has, however, been considered by Professor Cope as allied to the Lemuroidea and Insectivora. The structure of the teeth is like that obtaining in the present family, and the last lower molar has a third lobe, but the first premolar is wanting in both jaws. The skull presents, however, several Carnivorous features, and it is possible that this genus should rather be placed among the bunodont Condylarthra in the neighbourhood of *Periptychus*. The resemblance presented by the teeth of the latter to those of *Elotherium* and *Achænodon* is, indeed, so remarkable as to suggest that those two genera may be descendants of some unknown member of the Condylarthra very closely allied to the *Periptychidæ*.

Family Anthracotheriidæ.—In this family the dental formula is, with one exception, *I.* $\frac{3}{3}$, *C.* $\frac{1}{1}$, *Pm.* $\frac{4}{4}$, *M.* $\frac{3}{3}$; the upper true molars (fig. 1199) have broad, low crowns, with five columns, three of which are situated on the anterior and two on the posterior lobe; the columns in both upper and lower molars have a more or less distinctly selenodont structure; and the mandible has a descending flange at the angle. The Anthracotheres were probably in appearance somewhat between a Pig and a Hippopotamus, and doubtless dwelt in swamps and marshes. In the type genus *Anthracotherium* (fig. 1197) the selenodont structure of the teeth is less marked than in the next genus, with which it agrees in having four digits to each foot.

The species which approaches nearest to *Chœropotamus* in the structure of its molars is the small *A. silistrense* of the lower Siwaliks of India; but the still smaller *A. Gresslyi* (fig. 1197) from the Upper Eocene of Switzerland and Hampshire, agrees with that genus in having a diastema



Fig. 1197.—*Anthracotherium Gresslyi.* The left half of the palate and the upper cheek-dentition; from the Upper Eocene of Hordwell, Hampshire.

between the first and second upper premolars, and in the absence of the first lower premolar. In most of the other species all the cheek-teeth were in contact. This genus commenced in the Middle Eocene of Promina in Dalmatia, where it is represented by *A. dalmatinum*, which has been made the type of the genus *Prominatherium;* it was abundant in the Quercy Phosphorites and Lower Miocene of Europe, where it was represented by species like *A. magnum*, *A. valdense* of Lausanne, and *A. illyricum* of Tuscany, which attained the size of a Rhinoceros. It was represented in the Middle Miocene of France by *A. Cuvieri*, after which it died out in Europe, although it survived in India till the Upper Miocene, where it is known by the large *A. hyopotamoides* and the small *A. silistrense*. It is unknown in America.

The genus *Hyopotamus* generally has a more completely selenodont dentition than *Anthracotherium*, but in some species (fig. 1198) these characters are less marked, and thus indicate a complete transition between the two genera. In those species (fig. 1199) which have the most perfectly selenodont dentition the columns of



Fig. 1198.—The third left upper true molar of *Hyopotamus giganteus*. Upper Miocene, India.



Fig. 1199 — The third right upper true molar of *Hyopotamus bovinus*. Lower Miocene, Isle of Wight.

the true molars are taller than in the others. The first upper premolar is separated by an interval both from the canine and the second premolar. This genus apparently commenced in the Upper Eocene of Europe, and is especially characteristic of the Hempstead beds of the Isle of Wight, and of the Ronzon beds of France, where it is represented by the large *H. bovinus* (fig. 1199), *H. velaunus*, and the brachydont *H. porcinus*. In India it survived till the Upper Miocene, where it is represented by two species, one of which (fig. 1198) is the largest known form; it also occurs in the Miocene of North America. The name *Diplopus* has been applied to a form from the Upper Eocene of Hampshire, with only two digits to each foot, which has been referred to this family; since, however, its dentition is unknown this determination is only provisional, and it has been suggested that it may be a *Dichodon*, although it appears too large for the type species.



Fig. 1200.—A right upper true molar of *Merycopotamus dissimilis*; from the Pliocene of India.

Family Merycopotamidæ. — This family may be regarded as an offshoot from the *Anthracotheriidæ* in which the upper true molars (fig. 1200) have only four columns on their crowns; the dental formula being the same. It is probable that the feet were tetradactylate; and the mandible

has a descending flange. Some writers include this family in the *Anthracotheriidæ*, and perhaps this is really the better arrangement. The type genus is found only in the Pliocene Siwaliks of India and Burma, where it is represented by *M. dissimilis* (fig. 1200), and two smaller species. An imperfectly known but closely allied form from the Upper Miocene of Sind has been described under the name of *Hemimeryx*. In this and all the preceding families the odontoid process of the axis vertebra is peg-shaped.

Family Cotylopidæ.—This extinct North American family, usually known as the *Oreodontidæ*,[1] is regarded by Professor Cope as related to the *Anoplotheriidæ*, but with more completely selenodont teeth and less specialised feet, which are more like those of the Hippopotamus than those of the Ruminants; but their affinities are probably widely spread. Upper incisors are present; the true molars (fig. 1201) are selenodont, and those of the upper jaw usually have only four columns on their crowns; and the pre-

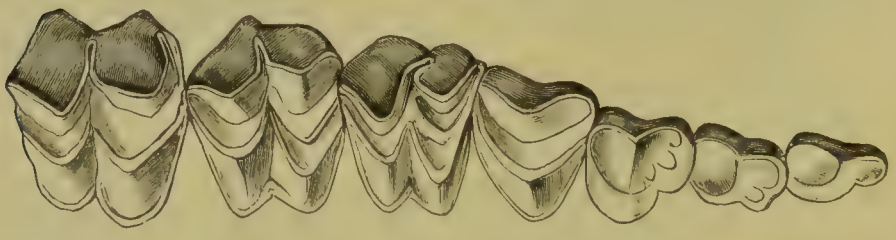


Fig. 1201.—Oral surface of the right upper cheek-teeth of *Eporeodon major*. Miocene, North America.

molars are simpler than the true molars, but are not secant. The lower canine is approximated to the incisors, and its function is taken by the first premolar, which has a tall crown biting behind the upper canine. The ulna, radius, tibia, fibula, metapodials, navicular, and cuboid are all distinct; and each foot carries four digits. The odontoid process of the axis vertebra is intermediate in shape between the peg of the Bunodonts and the half-cylinder of the Ruminants; the lachrymal bone frequently has a deep *larmial* depression; but the angle of the mandible has no descending flange.

In the type genus *Cotylops* (*Oreodon*) the dentition is *I.* $\frac{3}{3}$, *C.* $\frac{1}{1}$, *Pm.* $\frac{4}{4}$, *M.* $\frac{3}{3}$; the orbits are completely surrounded by bone, the premaxillæ are separate, the auditory bullæ not inflated; there are no vacuities in the bones of the face; and there is a small pollex in

[1] The name *Oreodon* being preoccupied by *Orodus* (*supra*, p. 940), involves the change of the family name. *Cotylops* was originally applied by Leidy to one species of the type genus.

the manus. In *Eporeodon*, or *Eucrotaphus*, the above characters are the same, with the exception that the tympanic bullæ are inflated; while *Merycochœrus* differs from the latter by the anchylosis of the premaxillæ. There are seven species in the latter genus. *Merychyus* is distinguished from *Merycochœrus* by the presence of vacuities in the lachrymal region. In *Leptauchenia*, which has been placed by some writers in the *Camelidæ*, such vacuities occur

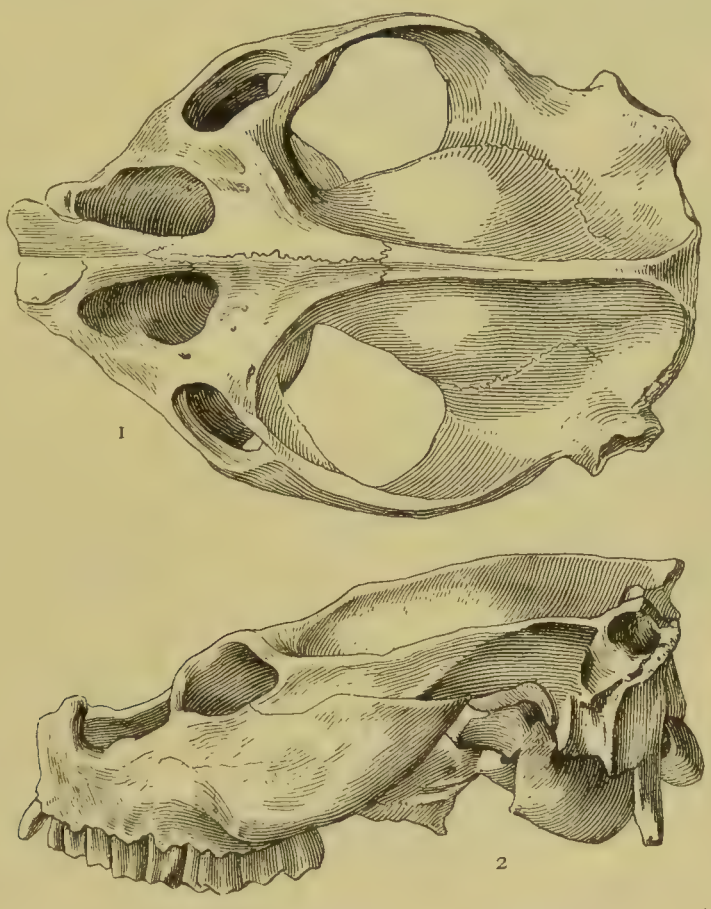


Fig. 1202.—Frontal (1) and left lateral (2) aspects of the cranium of *Cyclopidius emidinus*; from the Miocene of the United States. Reduced. (After Cope.)

close to the frontals, and the nasals become very small. Still more remarkable is the enormous development of these vacuities in *Cyclopidius* (fig. 1202), in which the upper incisors are wanting. *Pithecistes*, again, differs from all the preceding by the absence of the first premolar, and has but one pair of lower incisors. In the second division of this family, which includes the genera *Agriochœrus* and *Coloreodon*, the orbit is incompletely surrounded by bone, and the

fourth upper premolar has two outer columns in place of the single one of the typical section (fig. 1201). *Coloreodon* differs from *Agriochœrus* by having only three premolars, but it may be questioned whether this difference really affords sufficient grounds for generic distinction. The majority of the genera are confined to the White River Miocene of North America, but *Merycochœrus* extends into the Loup-Fork beds, which may be either of Upper Miocene or Lower Pliocene age. A tooth, apparently indistinguishable from the molars of *Agriochœrus*, has been obtained from the Pliocene of India.

Here may be noticed a remarkable form from the Upper Eocene of the United States, described under the name of *Protoreodon*. The organisation is said to be of the Cotylopine type, but the upper molars have five columns, as in the *Anthracotheriidæ* and *Anoplotheriidæ*. This genus probably indicates an ancestral type of the *Cotylopidæ*, which should perhaps be referred to a distinct family; it is, however, placed by Professor Cope near the Xiphodonts.

Family Anoplotheriidæ.—In this family the cheek-teeth are imperfectly selenodont; the crowns of the upper true molars (fig. 1204) carrying five columns, three of which are placed on the anterior, and two on the posterior lobe, or half, of the crown. All the bones of the limbs and feet remain distinct from one another; and there is no descending flange at the angle of the mandible. The functional digits may be either two or three in number; and the carpus and tarsus of the original genus are of that type to which the name inadaptive has been applied.[1] The anterior premolars are more or less perfectly secant; there is generally no diastema in the dental series; and the canines are short and compressed, and depart very widely from those of the *Anthracotheriidæ* and their allies, in which they resemble the corresponding teeth of the Carnivora. In the type genus *Anoplotherium* (in which may be included *Eurytherium* and *Diplobune*) the dentition (fig. 1204) is usually $I.\ \frac{3}{3}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{4}{4}$, $M.\ \frac{3}{3}$; but occasionally the first lower premolar is wanting. The tail (fig. 1203) is long; the functional digits may be either three or two;[2] and the third upper premolar has a well-developed inner tubercle. In the typical *A. commune*, of the

[1] In the inadaptive modification (*Anoplotherium*) the carpals of the aborted digits remain as useless lateral bones; while in the adaptive modification (*Hyotherium*) they shift their position, and take a share in the support of the large persistent digits.

[2] Prof. Cope has suggested that the forms with two digits should be excluded from this family, but it is the type species which presents this feature. The form with three functional digits is indistinguishable by dental characters from the typical *A. commune* with only two.

Paris gypsum, the columns of the cheek-teeth are comparatively tall, but in other species, like *A. cayluxense* of the Quercy Phosphorites (fig. 1204), they are shorter, and the teeth thus approximate to those of the brachydont species of *Hyopotamus*. This genus is confined to Europe, and is characteristic of the Upper Eocene (Lower Oligocene) and the Miocene of Ronzon in Puy-en-

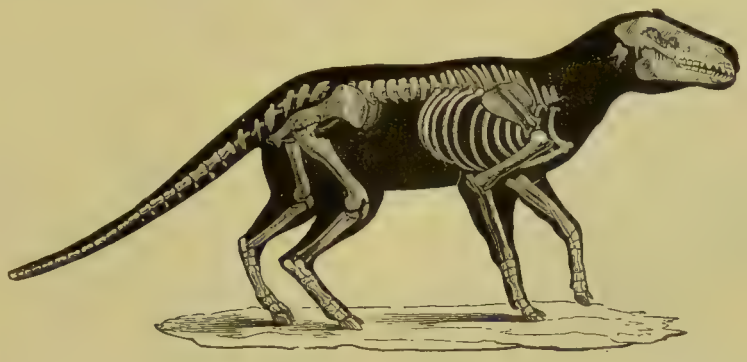


Fig. 1203.—Skeleton of *Anoplotherium commune*; Upper Eocene, Europe. Much reduced

Velay. The species from the South American Tertiaries originally referred to this genus is now known as *Proterotherium*, and is noticed under the Perissodactyla. The largest species was about the size of a Tapir. Here may be noticed five genera from the Quercy Phosphorites, some of which appear, on the whole, to be most nearly allied to *Anoplotherium*, although their teeth present certain resemblances to those of the Perissodactyla, in which suborder the last of the group is placed by some writers. Of these



Fig. 1204.—The last five right upper cheek-teeth of *Anoplotherium cayluxense*; from the Upper Eocene of France.

genera *Adeotherium* is characterised by the extreme complexity of the last upper premolar, which resembles the first true molar; *Metriotherium* is only known by the mandible, in which the premolars are simpler than in the type genus; and the true molars show some resemblance to those of *Lophiomeryx*; *Mixtotherium*, which is described from the palate, and is probably identical with

the preceding, also has simple premolars; *Myxochœrus* shows less completely selenodont teeth; while those of *Tapirulus* approximate to the molars of the *Tapiridæ*. In another direction we have *Dacrytherium* and *Plesidacrytherium*, from the Upper Eocene of France and England, in the former of which the first upper incisors of either side are separated from one another by a wide interval, while the first three premolars are more completely secant than in the type genus. The dental type of *Dacrytherium* leads on closely to that of *Xiphodon*, which, in accordance with the views of Professor Rütimeyer, is therefore placed in the same family, although some writers make it the type of another family, which is taken to include either *Cœnotherium* (Flower), or *Dichodon* (Schlosser). The true molars are like those of the type genus *Anoplotherium*, although more completely selenodont; but the first three premolars (fig. 1205) are much elongated and compressed; and the functional digits were reduced to two in each foot. In the typical forms there was no diastema in the dental series (which comprises the full typical number), but in certain smaller forms, separated by some writers under the name of *Xiphodontotherium*, a distinct diastema was developed. The Xiphodonts were animals of slender build, with limb-bones partly resembling those of *Anoplotherium*, and partly those of the more specialised Selenodonts; they are characteristic of the Upper Eocene of England and the Continent, the largest species being *X. magnus*, and the smallest *X.* (*Xiphodontotherium*) *secundarius*, of the Quercy Phosphorites. This genus, although not in the direct line, shows how a transition can be effected from the higher *Anthracotheriidæ* to the *Dichodontidæ*. *Rhagatherium*, from the Upper Eocene of Switzerland, is an allied genus. Finally, Dr Ameghino refers to this family the genus *Brachytherium*, from the Tertiary of South America; while Dr Schlosser would include in it the genus *Tetraselonodon*, founded on teeth from the Quercy Phosphorites, which have only four columns on the crown.

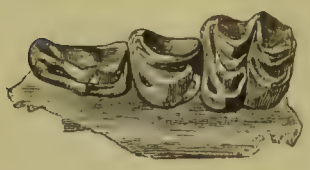


Fig. 1205.—The last two left upper premolars and first true molar of *Xiphodon gracilis*; from the Upper Eocene of Hampshire.

Family Cœnotheriidæ.—Following the classification of Professor Rütimeyer the next family we have to consider is that of which the type genus is *Cœnotherium*. All the genera have the full complement of teeth, and there are usually five columns, or cusps, on the crowns of the upper true molars (which may be either selenodont or bunodont); two of these columns being placed on the anterior and three on the posterior lobe of the teeth, thus reversing the arrangement obtaining in the *Anoplotheriidæ*. The type genus *Cœnotherium* comprises a number of species of small animals not

larger than a Rabbit, in which the teeth are selenodont; the anterior premolars more or less secant; the auditory bullæ inflated (fig. 1206) and the feet furnished with four complete digits. These small animals probably approximated in outward appearance to the living Chevrotains (*Tragulus*) of the Oriental region. In the typical forms there is no diastema in the dental series; but this is present in other species to which the name *Plesiomeryx* has been assigned

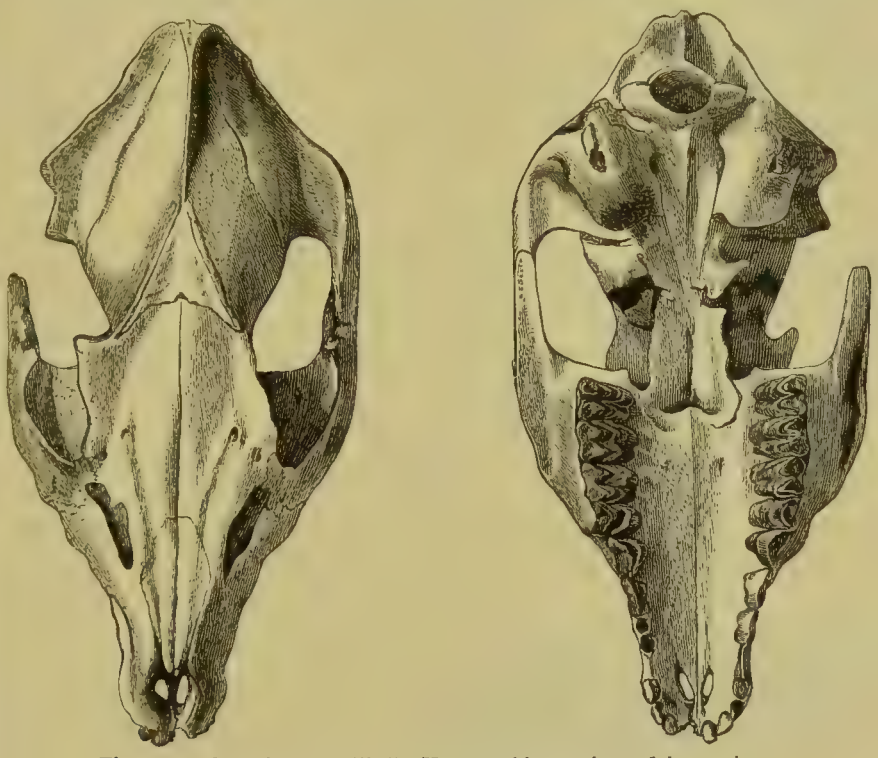


Fig. 1206.—*Cænotherium Filholi.* Upper and lower views of the cranium; from the Upper Eocene of Caylux.

by some writers. The limb-bones show characters connecting them both with the *Suidæ* and the Ruminants. In the figured cranium the nasals are peculiar for terminating in a point. This genus, of which the names *Zooligus* and *Microtherium* are also synonyms, ranges from the Upper Eocene (Lower Oligocene) of Vaucluse to the Lower Miocene (Upper Oligocene) of Allier. An allied genus is *Mouillactherium*, of the Quercy Phosphorites, in which the third upper true molar has but four columns; while yet another allied form from the same deposits has received the name *Oxacron*. The European Upper Eocene genus *Dichobunus* (*Didymodon*) is regarded by Professor Rütimeyer as a bunodont form closely allied to *Cænotherium*; *Dilotherium* and *Spaniotherium* being kindred genera

from the Quercy Phosphorites. The limb-bones, although all the four digits are developed, show considerable resemblances to those of the Ruminants, and it has been thought that *Dichobunus* may have been the direct ancestor of *Gelocus*. Here also may be mentioned the peculiar Upper Eocene European genus *Acotherulum*, in which the general form of the skull and teeth of the one known species seems to indicate affinity with *Dichobunus*, while the absence of the third cusp on the hinder lobe of the upper true molars, and the more completely bunodont structure of these teeth apparently indicates affinity with *Cebochœrus* and its allies, among which some writers prefer to place this genus.

Family Dichodontidæ.—According to the views of Professor Rütimeyer this family is taken to include several genera with a selenodont dentition in which the upper true molars have four columns; the type genus *Dichodon* presenting affinities with *Xiphodon*, while *Gelocus* and its allies are closely related to the *Tragulidæ* and the *Cervidæ*. Other writers, however, who do not attach such importance to the structure of the molars, place *Dichodon* with *Xiphodon* and make *Gelocus* the type of a distinct family.[1] In *Dichodon* the dental formula is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{4}$, $M.\frac{3}{3}$; the upper true molars having concave outer surfaces somewhat like those of *Hyopotamus*, while the earlier premolars are elongated and secant, and thus approach those of *Xiphodon;* there is no diastema. The limb-bones are unknown, but it is probable that there were only two functional digits. This genus occurs in the Upper Eocene of Hampshire. In *Lophiomeryx* (fig. 1207) from the Upper Eocene and Lower Miocene of the Continent, the hinder inner crescent of the upper true molars is imperfectly developed, and the first lobe of the lower true molars resembles that of *Anoplotherium*, while the second is Ruminant-like. The lower molars also resemble those of *Metriotherium* (p. 1329), and the family position of this genus, which is referred by Prof. Cope to the *Tragulidæ*, is still doubtful. *L. Gaudryi* from the Quercy Phosphorites has been made the type of the genus *Cryptomeryx*. In *Gelocus*, from the Quercy Phosphorites and Lower Miocene of Puy-en-Velay, it is not known whether upper incisors were present:

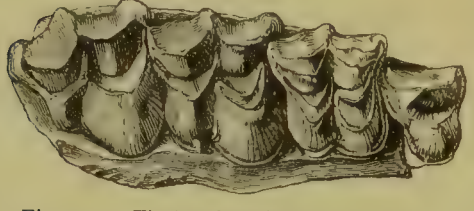


Fig. 1207.—The last four right upper cheek-teeth of *Lophiomeryx Chalaniati;* from the Quercy Phosphorites.

[1] Prof. Cope would include in this family the type genus and the American *Agriochœrus* and *Coloreodon*.

but the upper molars have low columns, with wide and open valleys, the external surface of each lobe resembling that of *Dichodon*. The navicular and cuboid bones of the tarsus were united, and the metatarsals fused into a cannon-bone, although the metacarpals were distinct. Allied to this genus are *Phaneromeryx* and *Protomeryx* of the Upper Eocene of France; while *Chœromeryx* of the Siwaliks of India may be provisionally referred to this family.

Family Tragulidæ.—The fossil forms included in this family indicate a transition from the typical genus on the one hand to the *Dichodontidæ*, and on the other to the *Cervidæ*. The upper true molars have four columns, and the earlier premolars are more or less completely secant. None of the genera were furnished with antlers, and it is probable that upper incisors were likewise always absent. In the existing forms the upper canines of the males (fig. 1208) are in the shape of tusks; there is a long diastema in both jaws; the third stomach, or 'psalterium,' is wanting; and the placenta is diffuse. The feet have supplementary toes, and the metacarpals of the third and fourth digits either unite late in life to form a cannon-bone, or remain (as in *Hyomoschus*) permanently separate. *Bachitherium* of the Quercy Phosphorites, in which there are three premolars in each jaw, shows resemblances both with *Gelocus*, *Hyomoschus*, and *Prodremotherium;* the upper teeth being very similar to those of the latter. In *Dorcatherium*, with which the existing *Hyomoschus* of Africa appears generically identical, the premolars are $\frac{3}{(3-4)}$, and are of a secant type, and thus indicate affinity with the *Dichodontidæ;* this genus is found in the Middle Miocene and Lower Pliocene of the Continent, and also in the Pliocene of India. *Tragulus*, which differs by the fusion of its metapodials into cannon-bones, and by never having more than three lower premolars, is now confined to the Oriental region, and is represented by one species in the Pliocene of India. *Leptomeryx*, from the Miocene of North America, has four premolars, of which the first three are simply secant as in *Tragulus*, while the fourth has an inner tubercle; there are four separate metacarpals, but the third and fourth metatarsals form a cannon-bone, as in *Gelocus*. In *Prodremotherium*, of the Quercy

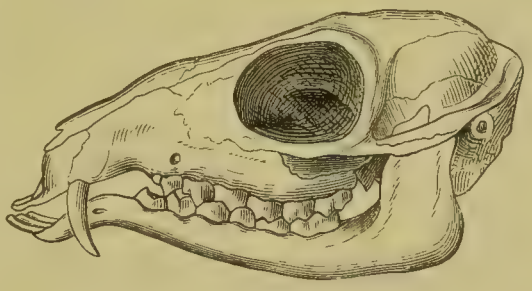


Fig. 1208.—Reduced side view of the skull of *Tragulus javanicus*.

Phosphorites, the dentition is almost, if not quite, indistinguishable from that of *Leptomeryx*, but cannon-bones are found in both limbs, although the union of the factors in the anterior ones is less complete than in the others. These two genera apparently connect *Gelocus* so completely with the cervine *Palæomeryx*, that we can have no hesitation in regarding them as representing the direct line of the descent of the *Cervidæ* from the *Dichodontidæ;* while we must consider the existing *Tragulidæ* as lateral offshoots from some nearly allied primitive stock. *Hypertragulus*, from the Miocene of North America, appears to be a form closely allied to *Leptomeryx*, but with the metatarsals separate.

Family Poëbrotheriidæ.—We must here leave for a short time the connection between the *Tragulidæ* and the *Cervidæ*, to consider the Camels and their allies, whose nearest existing relations are to be found in the former family. The *Poëbrotheriidæ* are represented typically by the genus *Poëbrotherium*, of the North American Miocene, in which the dental formula is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{4}$, $M.\frac{3}{3}$. The structure of the cheek-teeth is selenodont; in the feet the third and fourth metacarpals remain distinct, the second and third being rudimentary; the carpus has a trapezium; and the navicular and cuboid are not fused together. The structure of the cervical vertebræ is the same as in the *Camelidæ*, of which this family may be regarded as the ancestral type; but in other respects there are signs of affinity with the *Tragulidæ*. The type species of *Poëbrotherium* was scarcely larger than a Fox. In the John Day Miocene of Oregon an allied form has received the name of *Gomphotherium;* while *Leptotragulus* of the Upper Eocene of the United States may be the ancestral form of both the Miocene genera.

Family Camelidæ.—In the Camels the cheek-teeth are selenodont and quadricolumnar, but of somewhat simpler structure than those of the following families. The navicular and cuboid remain distinct, but the metapodials unite to form a cannon-bone. At least one pair of upper incisors is present; and in the cervical vertebræ the arterial canal passes obliquely through the anterior part of the pedicle of the neural arch, and is thus confluent posteriorly with the neural canal; a similar condition prevailing in *Macrauchenia* among the Perissodactyla. At the present day this family is represented by *Camelus* of the Old, and *Auchenia* of the New World; but it appears to have originated in the latter, where a large number of forms have been found. The most generalised member is *Protolabis*, of the Miocene of the United States, in which the dentition is numerically the same as in *Poëbrotherium*, on which grounds Professor Cope makes it the type of a distinct family. In *Procamelus* (fig. 1210, B, C) of the Lower Pliocene or Upper Miocene

of the same area, the incisors were reduced (as in all the other forms) to $\frac{1}{3}$, but there were still four premolars, although the first is isolated and the second very small. *Pliauchenia* (which is perhaps identical with *Homocamelus*) has only three lower premolars, and occurs in the

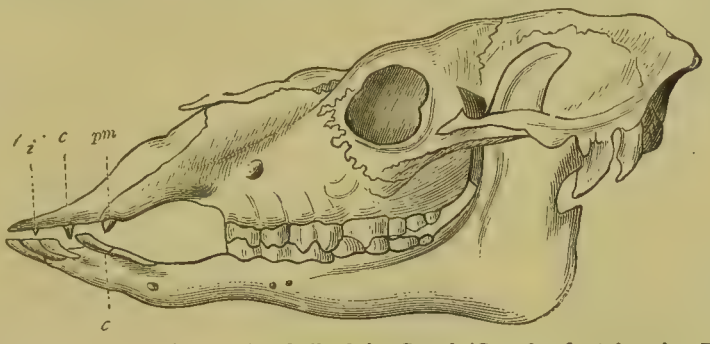


Fig. 1209.—Left lateral view of the skull of the Camel (*Camelus bactrianus*). Reduced. *i*, Upper incisor; *c*, *c*, Canines; *pm*, Isolated premolar. The maxillo-premaxillary suture should have been placed in front of *c* instead of in front of *pm*.

Loup-Fork-beds of North America. In *Camelus* again (fig. 1209) the normal adult formula of the cheek-teeth is $Pm.\ \frac{2}{3}$, $M.\ \frac{3}{3}$; the first upper premolar being canine-like, and separated by a long interval from the penultimate tooth of that series. This genus is confined to the Old World; the earliest known species occurring in the Pliocene of India, and another form (*C. Thomasi*) in the Pleistocene of Algeria. The molars of the Siwalik species show characters now only found in *Auchenia*. The latter generic term is here taken

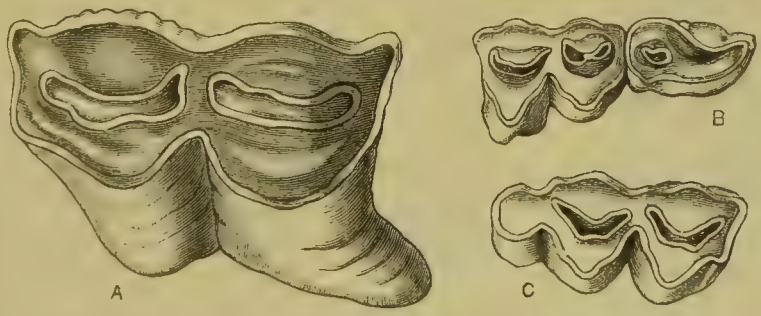


Fig. 1210.—A, First left lower true molar of *Auchenia hesterna*, Pleistocene, California; B, Fourth right upper premolar and first true molar of *Procamelus virginiensis*, Miocene, North America; C, Third right lower true molar of do.

to include a number of fossil New World forms some of which have been generically separated under the names of *Hemiauchenia*, *Palauchenia*, *Protauchenia*, *Holomeniscus*, and *Eschatius*. In the

existing species, which occur fossil in the caves of Brazil, the premolars are normally $\frac{2}{2}$ in number, but there is often but one of these teeth in the lower jaw; in *A.* (*Palauchenia*) *magna* from the Pleistocene of Mexico, there were always two and occasionally three lower premolars; while in a Pleistocene South American species (*Hemiauchenia*) there were three premolars in both jaws. In *A.* (*Holomeniscus*) *hesterna* (fig. 1210, A), from the Pleistocene of North America, on the other hand, the premolars were reduced to one in each jaw; while *A.* (*Eschatius*) *vitakeriana* has the same number, but is distinguished by the simpler nature of the upper one. The majority of the species were of comparatively small size, but *A. magna* and *A. hesterna* were equal in bulk to the Camels of the present day.

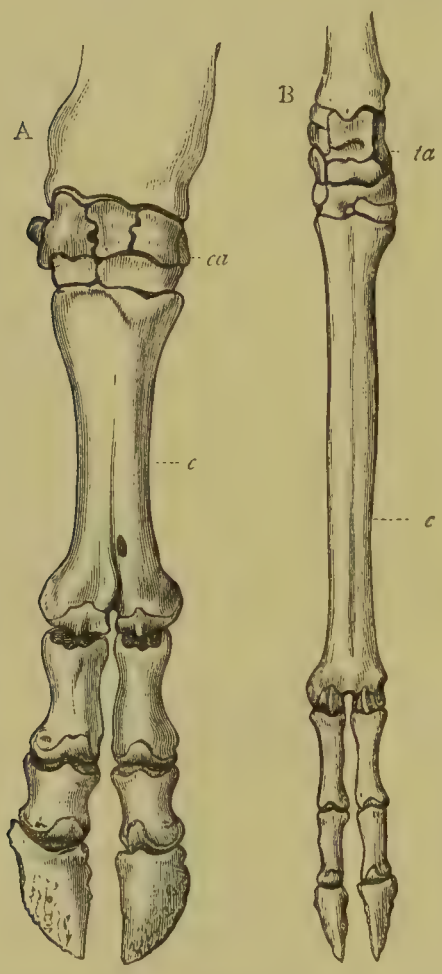


Fig. 1211.—A, Dorsal aspect of the right manus of Ox (*Bos taurus*); B, Do. of right pes of Red-Deer (*Cervus elaphus*). Reduced. *ca*, Carpus; *ta*, Tarsus; *c*, Metapodium (cannon-bone).

Family Cervidæ.—The present and three following families of the suborder collectively constitute the Pecora of recent Zoology;—a group well defined at the present day, but, as already mentioned, connected in past epochs most intimately by this family with the *Tragulidæ*. The dentition of the entire group is usually $I.\frac{0}{3}$, $C.\frac{(0-1)}{1}$, $Pm.\frac{3}{3}$, $M.\frac{3}{3}$; upper incisors being invariably absent. The true molars are perfectly selenodont, and the upper ones carry four columns; the second premolar is always in contact with the third; there is a long interval, or diastema, between the lower premolars and canine; and the latter is approximated to, and closely resembles the incisors. The third and fourth metapodials (fig. 1211) coalesce into a cannon-bone; the navicular and cuboid of the tarsus are likewise united; and the odontoid process of the axis vertebra forms a spout-like

half-cylinder. Moreover, in all existing members of this group the lateral metapodials are either incomplete or totally wanting (fig. 1211); the stomach is composed of four complete cavities; and the placenta develops structures known as cotyledons. On the skull either horns or antlers are very generally present, at least in the males of recent forms.

In the *Cervidæ* upper canines are generally present, although with a few exceptions they are of comparatively small size; the cheek-teeth, and more especially in the earlier forms, are very generally of a more or less brachydont structure, the first true molar being invariably of this type; and the upper premolars always have both an inner and an outer column, and are never simply secant like those of the existing *Tragulidæ*. In the skull there is always a large vacuity in front of the lachrymal, which prevents that bone from articulating with the nasal. In a large number of forms antlers are present in the male, and in *Rangifer* also in the female. Antlers, it may be observed, are outgrowths of true bone arising from the frontal

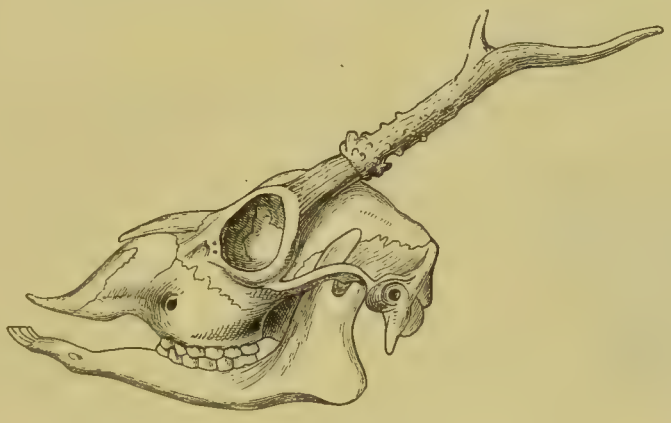


Fig. 1212.—Reduced left lateral aspect of the skull of the Roebuck (*Capreolus caprea*).

region of the skull (fig. 1212), which during their development are invested with a vascular, hairy skin. On the completion of their growth a constriction of the blood-vessels near their base is usually brought about by the formation of a *burr*, and above this point the skin peels off and leaves the bone bare and insensible; after a time the antler is shed, leaving a more or less elongated pedicle attached to the skull, from which a new antler is developed. In young animals the antlers are simple, and in those species in which they finally attain a great complexity, this is acquired gradually in successive annual growths. Each antler always consists of a main stem or *beam*, and usually of one or more branches or *tines;* of which the one immediately above the burr

is termed the *brow*-tine. The lateral digits are nearly always present, and the distal extremities of the metapodials may be preserved. The existing Deer have been divided into the Plesiometacarpalia (*Cervus* and *Cervulus*), and the Telemetacarpalia (*Alces*, *Capreolus*, *Cariacus*, and *Rangifer*); the former, which mainly inhabit the Old World, characterised by the retention of the proximal, and the latter of the distal extremities of the lateral metacarpals. As in many analogous instances, the development of the antlers of the individual is paralleled by their development in the family; since we find that many of the earlier members were totally unprovided with these appendages, and that their extreme complexity in the more specialised forms was not acquired until a late period in the geological scale.

The least specialised members of this family form the closely allied extinct genera *Amphitragulus* and *Palæomeryx*. In the former there are four lower premolars, and antlers were entirely absent; the crowns of the molars being low. The largest species was somewhat bigger than the Musk-Deer, and the genus is characteristic of the Lower Miocene of the Continent. *Palæomeryx* (*Dremotherium*, *Dicroceros*, and *Micromeryx* being included) has only three lower premolars, except in one species; and the upper true molars (fig. 1213), like those of *Amphitragulus*, were brachydont, and had no distinct accessory column between the inner crescents. In one species (*P. Feignouxi*) the lateral metacarpals were perfect, although very slender, and the males had long upper canines like those of the Musk-Deer, but no antlers; this species being the earliest, and occurring in the Lower Miocene of France. In *P. furcatus* (*Dicroceros elegans*), of the Middle Miocene, simple antlers were, however, present, and the canines were apparently small. *P. Bojani*, of the French Middle Miocene, and *P. sivalensis* (fig. 1213), of the Pliocene of India, were as large as a Red Deer; and the latter species, together with another from the Pliocene of China, were the last representatives of the genus, of which the latest appearance in Europe is in the Middle Miocene of Sansan, in France. *Platyprosopus*, from the latter beds, is distinguished by the great projection of the angle of the mandible. To the existing Oriental genus *Cervulus*, in which the molars are more hypsodont, and simple antlers mounted on a long pedicle are present, may be provisionally referred *C. dicranoceros* (fig. 1214, A), of the Pliocene of Eppelsheim. There is some uncertainty as to the earliest appearance of the genus *Cervus*, but it not improbably dates from the Middle Miocene, and was abundant



Fig. 1213. — Left upper true molar of *Palæomeryx sivalensis*. Pliocene, India.

in the Lower Pliocene; at the present day it ranges throughout the Palæarctic region, but is unknown in the Ethiopian region and the greater part of America. This genus, as we have already observed, belongs to the Plesiometacarpalian section; the antlers may be of

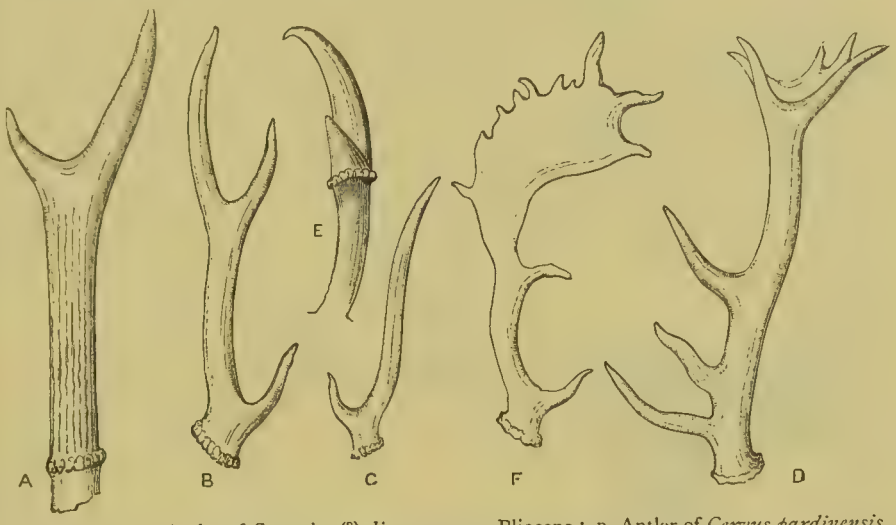


Fig. 1214.—A, Antler of *Cervulus* (?) *dicranoceros*—Pliocene; B, Antler of *Cervus pardinensis*—Pliocene; C, Antler of the Red Deer (*Cervus elaphus*) in the second year; D, Antler of the same in its fully-grown condition; E, Antler and bony pedicle of the frontal bone of the Muntjak (*Cervulus muntjak*); F, Antler of the Fallow Deer (*Cervus dama*).

extreme complexity; and the hinder molars are either brachy- or hypsodont, there being frequently an inner accessory column in the upper true molars.

The genus is divided into a number of groups, of which the distribution can only be briefly noticed. The most aberrant is the *Tetracerotine* group, formed by *Cervus tetraceros* of the French Pliocene, in which the antlers approximate to those of *Cariacus*. The *Axine* group, now confined to the Oriental region, in which the molars are more hypsodont than usual, and the antlers are rounded and comparatively simple, is represented by several species, such as *C. pardinensis* (fig. 1214, B), in the Pliocene of Europe, while the living *C. axis* occurs in the Pleistocene of Madras. The Oriental *Rucervine* group has a representative in *C. sivalensis*, of the Pliocene of India; while the allied *Rusine* group, of the same region, in which the antlers are still comparatively simple, and with their beam often strongly grooved, is known in a fossil state by the remains of existing species from the Pleistocene of India. In the *Elaphine* group, which includes the Canadian Wapiti (*C. canadensis*), the Red Deer (*C. elaphus*) of Europe and North Africa, together with some large species from the Palæarctic region, the antlers (fig. 1214, C, D), although still rounded, are often cupped at their summits, and carry a second, or *bez-tine*, immediately above the brow-tine. In this group remains referable to the existing Red Deer (*C. elaphus*) are of common occurrence in the Pleistocene of Europe. Some of the fossil antlers and jaws indicate, however, much larger animals than any Red Deer now existing,

and it has been suggested that these remains belong either to *Cervus maral* of Persia, or to the Wapiti (*C. canadensis*) of North America. Both these forms are, however, closely allied to the Red Deer, and it appears preferable to regard all the European fossils as referable to a single species from which the three existing types are derived. There is, however, the name *C. spelæus* for the large fossil form (which is of earlier date than the name *C. maral*), if that be really distinct from *C. elaphus*. Remains of the Wapiti are recorded from the Pleistocene of the United States.

The *Eucladocerotine* group comprises *C. Sedgwicki* of the Norfolk Forest-bed and the Upper Pliocene of Italy, in which the antlers are



Fig. 1215.—Skeleton of the Irish Deer (*Cervus giganteus*); from the Pleistocene of Ireland. Greatly reduced. (After Owen.)

more complex than in any other species. In the *Damine* group the antlers (fig. 1214, F) have their terminations palmated, and the brow-tine simple; the existing Fallow-Deer (*C. dama*) occurs in the bone-caves of Gibraltar, while allied forms are found in the English Forest-bed and Crag; the most noteworthy being *C. verticornis*, in which the brow-tine

is bent sharply downwards. The last group which it is necessary to mention here is the *Megacerotine*, which contains only the Irish Deer (*Cervus giganteus*, fig. 1215), characterised by its enormous palmated antlers (fig. 1216), which diverge at right angles from the plane of the frontals, and have a distinct brow- (*Br*) and bez- (*Bz*) tine, and a small posterior tine (*PT*) on the opposite side of the beam to the bez-tine. Remains of this fine species are found in the Pleistocene of Northern Europe, and are especially abundant in the bogs of Ireland, where specimens have been found with a spread of more than eleven feet between the tips of the antlers.

Passing to the Telemetacarpalian genus *Rangifer*, which is at once characterised by the peculiar form of the antlers and their presence in both sexes, we find remains of the existing Reindeer (*R. tarandus*),

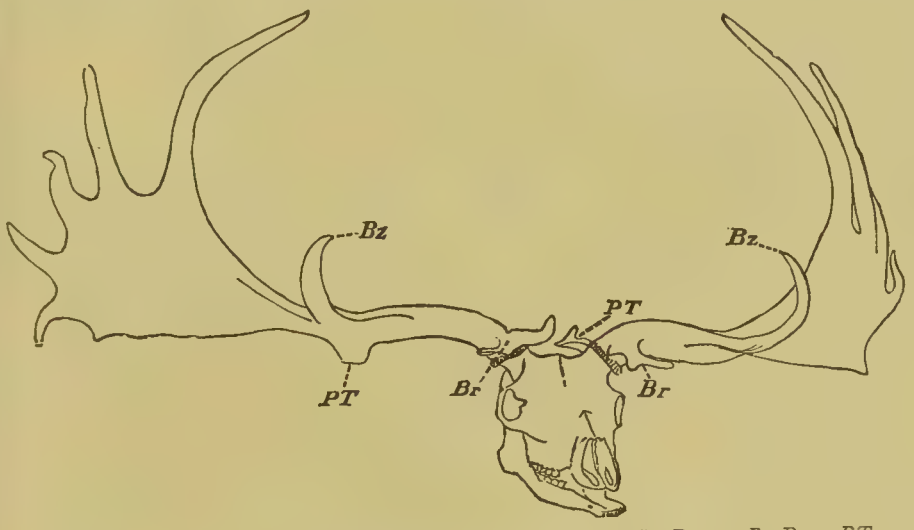


Fig. 1216.—Skull and antlers of *Cervus giganteus*. Reduced. *Br*, Brow-, *Bz*, Bez-, *PT*, Posterior tine. (After Scott.)

now confined to the higher latitudes of the Northern Hemisphere, abundant in the Pleistocene of a large portion of Europe. In *Alces* the Elk, or Moose (*A. machlis*), of the northern parts of Europe and America, occurs in the Pleistocene of the same regions; while an extinct species has been described from the Norfolk Forest-bed. The antlers (fig. 1217) have no bez-, and apparently no brow-tine, but are divided into an anterior forked branch (*A*) and a posterior palmated one (*P*). A very remarkable form from the Pleistocene of North America, described under the name of *Cervalces*, appears to connect *Alces* with *Cervus*, although it belongs clearly to the Telemetacarpalian section. Thus the antlers (fig. 1218) are superiorly divided into an anterior (*A*) and posterior (*P*) branch; but below the latter there occur two tines (*Bz* and *PT*), which Dr Scott regards as probably corresponding to the bez- and posterior tines

of the Irish Deer. And we may likewise trace an intermediate type in the vertical height of the skull, and the form and connections of the nasal and premaxillary bones. In *Capreolus*, where the antlers are simple and rounded, the existing Roe (*C. caprea*, fig. 1212) occurs in the European Pleistocene; while *C. cusanus*, of the French Pliocene, is regarded as the ancestor of that species; and the peculiar *C. Matheroni*, of the Lower Pliocene of both Greece and France, is provisionally referred to the same genus. *Cariacus*, again, which is peculiar to the New World, and is characterised

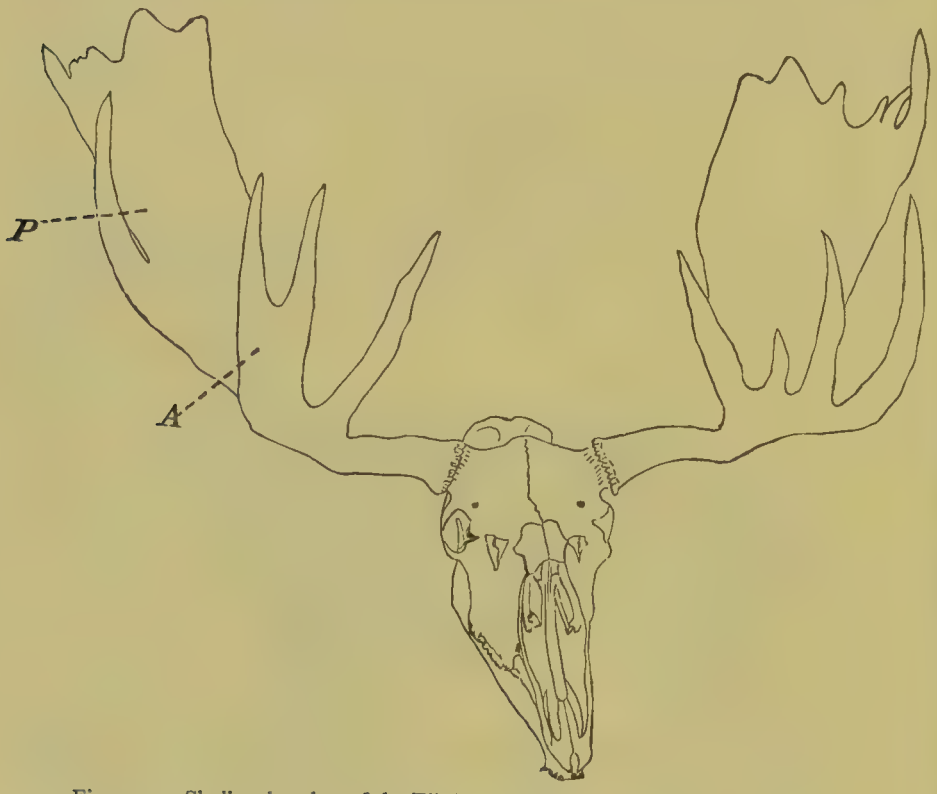


Fig. 1217.—Skull and antlers of the Elk (*Alces machlis.*) Reduced. *A*, Anterior; *B*, Posterior branch. (After Scott.)

either by very simple prong-like antlers, or by a more complex form totally unlike those of any existing European members of the family, is represented by several existing, and perhaps by some extinct, species in the Pleistocene of South America. Lastly, it should be observed that antlered Deer occur in the Tertiaries of North America, and the name *Blastomeryx* has been applied to one form which is regarded as the ancestor of *Cariacus*.

All the preceding existing genera belong to the subfamily *Cervinæ*, but the Musk-Deer (*Moschus*), of the Himalaya and regions to the northward, is the type of a second subfamily—the *Moschinæ*. This

genus, in which there are no antlers, and the upper canines of the male attain an excessive development, not improbably occurs fossil in the Pliocene of the Siwalik Hills.

Family Giraffidæ.—In this family, which is taken to include the *Sivatheriidæ* of some authors, the cranial appendages, when present, appear to be intermediate in character between those of the *Bovidæ* and *Cervidæ*. The teeth are more or less brachydont, and invested with a rugose enamel; their number being *I.* $\frac{0}{3}$, *C.* $\frac{0}{1}$, *Pm.* $\frac{3}{3}$, *M.* $\frac{3}{3}$. The type genus *Giraffa* (*Camelopardalis*), which at the present day is represented only by *G. camelopardalis* of Africa, is closely allied to the *Cervidæ*, in which family it is included by Professor Rütimeyer; the frontal appendages consist of a pair of

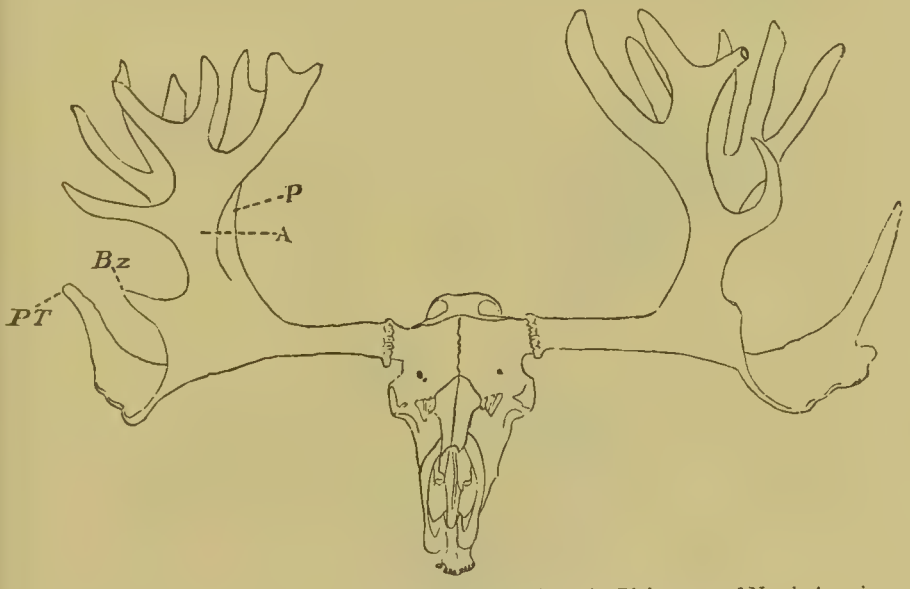


Fig. 1218.—Skull and antlers of *Cervalces americanus;* from the Pleistocene of North America. Reduced. Letters as in figs. 1216 and 1217. (After Scott.)

short, erect, bony processes, at first connected by suture, but subsequently anchylosed to the skull, which are covered with hairy skin, and are present in both sexes. Anteriorly to these there is a median process on the frontals and nasals, which is sometimes termed a third horn. There are no traces of lateral digits; the humerus has a double bicipital groove; there is a lachrymal vacuity in the cranium; and the neck and limbs are enormously elongated. Fossil species occur in the Lower Pliocene of Greece, Persia, India, and China. *Vishnutherium*, of the Siwaliks of Burma and India, appears to be an allied genus, with shorter limbs, but the

cranium is unfortunately unknown. The next place in the series is occupied by *Helladotherium*, of the Lower Pliocene of Greece, India, and perhaps Persia, in which the cranium is devoid of appendages, and the molar teeth become more like those of the Elk. The limbs are comparatively short and stout; the cranium has no lachrymal vacuity; and the one known species was of considerably greater bulk than the Giraffe. With *Hydaspitherium*, of the Pliocene of North-western India, we enter the group in which the cranium was provided with large branching antler-like appendages, although the exact nature of their covering is unknown. These appendages in this genus rise from a common base situated immediately in advance of the occiput, but their form is not known; there were lachrymal vacuities in the cranium. An apparently allied form, from the Pliocene of Persia, has been named *Urmiatherium*. In *Bramatherium*, of the Pliocene of Western India, there were two



Fig. 1219.—Skull of *Sivatherium giganteum*; reduced. Pliocene, India. The position of the hinder antlers should probably be reversed.

pairs of these antler-like appendages, the anterior pair arising from a common base, and being of large size. Lastly, we have *Sivatherium* (fig. 1219), of the Pliocene Siwaliks of North-eastern India, in which the neck and limbs were not developed beyond the normal proportions. There are two pairs of cranial appendages, the bases of each being separate. The anterior pair are conical, like those of

the Giraffe; while the posterior ones are palmate, and resemble the antlers of the Elk. The latter pair are marked by the impressions of large blood-vessels, as in the *Cervidæ*, but do not show the burr characteristic of that family, from which it is inferred that they were not shed. There is no lachrymal vacuity in the cranium; the nasals are short and arched; and the bones of the skeleton approximate in structure to those of the *Cervidæ*. Some authorities regard this genus as most closely allied to brachydont Antelopes like *Strepsiceros*, but it appears to be so intimately connected with the preceding forms that it seems imperative to place it in the same family, although it may indicate an approximation to the *Bovidæ*.

The remarkable genus *Samotherium*, of the Lower Pliocene of the Isle of Samos, is referred by Dr Forsyth-Major to the present family, although its skull makes a remarkable approximation to that of the antelopoid genus *Palæotragus*. The females were hornless, but the males had a pair of small horns immediately above the orbit. The molars are described as being very like those of the Giraffe.

Family Antilocapridæ.—This family is now represented only by the American Prong-buck (*Antilocapra*), in which the horns are of the same nature as in the *Bovidæ*, but differ in being bifurcated, and in the shedding of their sheath. Remains of *Antilocapra* occur in the Pleistocene of North America; and it is thought that *Cosoryx*, of the Pliocene of the same country, may have been the direct ancestor of the existing genus.

Family Bovidæ.—In this, the last, family are comprised the most specialised members of the whole suborder, such as the Antelopes, Goats, Sheep, and Oxen. The general characters of the greater part of the skeleton are the same as those mentioned under the head of the *Cervidæ;* but a remarkable difference is found in respect of the frontal appendages. These appendages (fig. 1222) are paired, and consist of persistent bony processes, into which the air-cells from the frontal diplöe often extend; they are generally subconical or triangular, and often twisted, but never branched. These "horn-cores," as they are termed, are covered with the true horns, which are composed of an epidermal fibrous structure, and are never shed. The males of all existing genera in the wild state are furnished with these horns, and they are also present, although of smaller size, in the females of the great majority. In certain domesticated races of so-called *polled* Sheep (fig. 1220), Goats, and Cattle, the horns are, however, wanting in both sexes; and this peculiarity is with great probability regarded as an instance of reversion, since these appendages are also wanting in some allied Tertiary forms of two of these groups. In the cranium there is generally no lachrymal vacuity, and the lachrymal

consequently articulates largely with the nasal (fig. 1220); but in certain Antelopes this vacuity is present, when the relations of these bones are the same as in the *Cervidæ*. Another very characteristic feature of the *Bovidæ*, as a whole, is the hypsodont character of their cheek-dentition. In many of the Antelopes (fig. 1221) this feature is only moderately developed, but in the Sheep, Goats, and Oxen it is carried to an excessive degree; and in the latter group the valleys of the teeth are filled up by a coating of cement. This feature, like that of the relations of the lachrymal, is, however, not absolutely distinctive of the *Bovidæ*, since we find many Antelopes

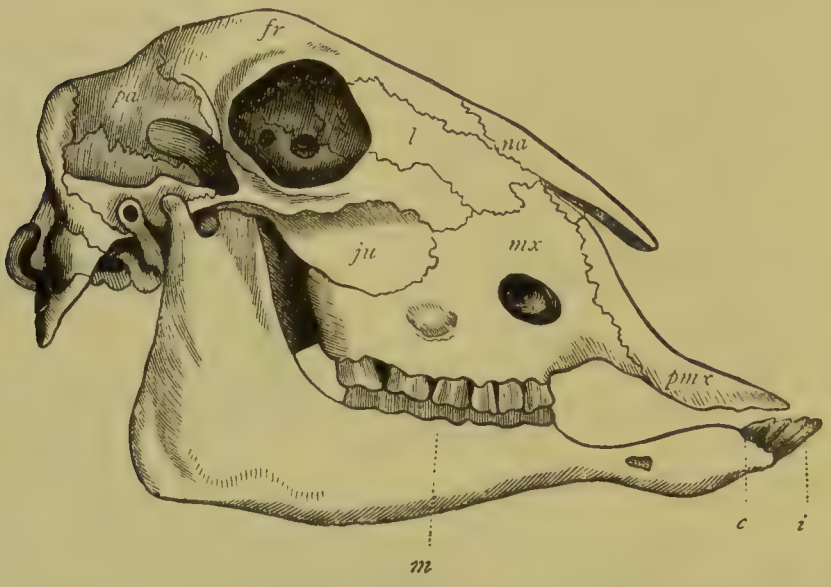


Fig. 1220.—Skull of a hornless Sheep (*Ovis*). Reduced. *i*, Incisors; *c*, Canines; *m*, Cheek-teeth; *pmx*, Premaxilla; *mx*, Maxilla; *na*, Nasal; *l*, Lachrymal; *ju*, Jugal; *fr*, Frontal; *pa*, Parietal. (After Owen.)

(and especially those having a lachrymal vacuity) with a decidedly brachydont dentition. The upper true molars frequently have a large accessory inner column (fig. 1221). Functional canines are wanting in all existing forms. The lateral digits may or may not be present, but in no living form is there a distal remnant of the lateral metapodials.

This family does not apparently date further back than the Middle Miocene, where it is represented by members of its least specialised group, the Antelopes; the Sheep and Oxen not appearing till the Pliocene. It has been suggested that the family originated from the same ancestral forms as the *Cervidæ*.

Commencing with the Antelopes, and confining our attention to those forms in which the genus has been more or less accurately determined, we find in the *Alcelaphine* section, which is now con-

fined to Africa and Syria, the existing genus *Alcelaphus* represented in the later Tertiaries of Algeria, and also in the Pliocene Siwaliks of India; the species from the latter deposits being apparently allied both to the Hartebeast (*A. caama*) and the Bontebock (*A. pygargus*). These antelopes have recurved or lyre-shaped horns; their skull has no supraorbital pits, and may have a very long face; while the molar teeth are very narrow. In the *Cephalopine* section, comprising Indian and African species of comparatively small size, the existing Four-horned Antelope (*Tetraceros quadricornis*) is found in a fossil state in the cave-deposits of Madras;

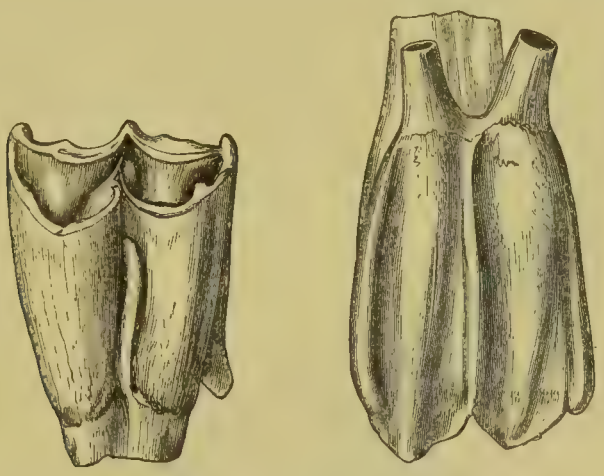


Fig. 1221.—Inner and outer views of the second left upper true molar of the Nilghai (*Boselaphus tragocamelus*). Recent; India.

while an extinct species occurs in the Siwaliks. The African genus *Cephalopus* may perhaps also occur in the latter deposits. The *Cervicaprine* section is now confined to Africa, and includes some very large antelopes in which the females are hornless. *Cobus*, in which the skull has well-marked supraorbital pits, appears to be represented in the Indian Siwaliks by species as large as some of the African forms. In the Pliocene Pikermi beds of Greece an antelope with round lyrate horns, described as *Helicophora*,[1] appears to be allied in some respects with *Cobus*, although it has lachrymal vacuities, but no distinct supraorbital pits. In the typical *Antelopine* section, which is allied in many respects to the preceding, there are always well-developed supraorbital pits, and the molar teeth are hypsodont, and resemble those of the sheep. The type genus *Antilope*, which has round and spirally twisted horns, is known in the Pleistocene of India by remains of the one existing species *A. cervicapra* (Black-buck); the existing Siberian *Saiga tartarica* is

[1] Originally described under the preoccupied name of *Helicoceros*.

found fossil in the cave-deposits of Europe; while the Afro-Asiatic genus *Gazella*, in which the lyrate horns are laterally compressed, occurs in the Pliocene of Europe, Africa, and India, as well as in the Norfolk Forest-bed. The *Hippotragine* section may be taken to include the existing African genera *Oryx*, *Addax*, and *Hippotragus*, and is characterised by the long and straight, or backwardly-curved horns, the absence of supraorbital pits in the skull, and the broad and hypsodont upper molars, which resemble those of the oxen. In a fossil state this section is represented by *Hippotragus* in the Indian Siwaliks; and also by the extinct *Palæoryx*, of the older Pliocene of Greece, Italy, Samos, and France, which appears to have been closely allied to *Oryx*, although showing some affinity to *Hippotragus*. The last section into which the true existing antelopes may be divided is the *Tragelaphine*, comprising *Boselaphus* in India, and *Tragelaphus*, *Strepsiceros*, and *Oreas* in Africa. In the Indian genus, of which the Nilghai is the only existing representative, the horns are short and upright, and are not present in the females, while the dentition is hypsodont (fig. 1221); fossil forms occur in India from the Siwaliks upwards. In the African forms the horns are spirally twisted, with two more or less well-defined longitudinal ridges, the skull has deep supraorbital pits and lachrymal vacuities, but no pit in the lachrymal itself, and the molars are broad and brachydont like those of the *Cervidæ*. *Strepsiceros* (Kudu), in which the anterior ridge on the horns is much the stronger of the two, apparently occurs in the Indian Siwaliks, which may also contain a representative of the allied *Oreas* (Eland). The extinct *Palæoreas* (fig. 1222), of the Lower Pliocene of Europe and Algeria, appears to have been allied to both the preceding genera; while the so-called *Antilope torticornis*, of the Pliocene of France, has the posterior ridge of the horns the most developed, as in the existing *Tragelaphus*, to which genus it has, indeed, been referred. The remarkable *Protragelaphus*, of the Lower Pliocene of Greece, differs from all the preceding genera in that the horns have only a posterior longitudinal ridge, in the absence of supraorbital pits, and in the development of lachrymal depressions like those of the *Cervidæ*. With the *Rupicaprine* section of this family we come to genera showing characters connecting the true antelopes with the goats; but the only definitely known fossil remains belong to the existing alpine Chamois (*Rupicapra*), which occurs fossil in the cave-deposits of the Continent. Under the name of the *Palæotragine* section may be included three extinct Tertiary genera having the laterally compressed horn-cores of the goats, but the upper molars more or less like those of the brachydont antelopes. The earliest of these genera, and indeed of all the antelopes, is *Protragoceros*, of the Middle Miocene of France, one of the species having been long

since described as *Antilope clavata* (*sansaniensis*). These were small forms, with short horns, and the crowns of the molars very short and moderately wide. In *Palæotragus* and *Tragoceros*, of the Lower Pliocene of Greece and Samos, the horns were larger, and the molars wider. The former genus is considered to be allied to *Samotherium*, noticed among the *Giraffidæ*. The true Goats and Sheep, collectively forming the section *Caprinæ*, are characterised by their more or less laterally compressed and often angulated horn-cores, which may be either curved backwards, as in the Ibex, spirally twisted, as in the Markhoor, or with a peculiar outward curvature and twist, as in the Sheep; the horns themselves being frequently



Fig. 1222.—Left lateral view of the cranium of *Palæoreas Lindermayeri;* from the Lower Pliocene Pikermi beds of Greece. Reduced. The lachrymal vacuity is omitted. (After Gaudry.)

marked on the anterior surface by transverse ridges. In all the genera the dentition is markedly hypsodont, and in existing forms the accessory inner column of the upper true molars is wanting. None of them show a lachrymal vacuity; but in the Sheep there is generally a deep depression (larmier) in this bone, which is absent in the Goats. *Capra* may perhaps occur in the Upper Pliocene of France; it is represented in the Pliocene of the Indian Siwaliks by one species (*C. sivalensis*), which is probably the ancestor of the Himalayan Thar (*C. jemlaica*); by another species equally closely allied to the Markhoor (*C. Falconeri*), of the same region; and not

improbably by a third allied to the Himalayan Ibex (*C. sibirica*). Remains of the Pyrenean Ibex (*C. pyrenaica*) are found in the Pleistocene cave-deposits of Gibraltar; and those of the common Goat (*C. hircus*) in the turbaries and fens of England. The very remarkable hornless genus *Bucapra*, from the Siwaliks of India, has a skull presenting a great resemblance to that of the Goats, but cheek-teeth like those of the Oxen. The true Sheep (*Ovis*) appear to be a group of very late origin, and are scarcely known in a fossil condition; a large species has, however, been described from the Norfolk Forest-bed as *O.* (*Caprovis*) *Savigni*, which was apparently allied to the existing Argali. The Musk-Ox (*Ovibos*) of the Arctic regions, which forms a connecting link between the *Caprinæ* and *Bovinæ*, occurs fossil in the Pleistocene of Europe and Alaska; while two closely allied forms, from the Pleistocene of Kentucky and Arkansas, have been respectively named *O.* (*Boötherium*) *bombifrons* and *O. cavifrons*.

The members of the *Bovine* section, comprising about thirteen recent species distributed over the greater part of Europe, Asia, Africa, and North America, agree with the *Caprine* section in having no lachrymal vacuities, but differ from the recent members of that section in having the crowns of the cheek-teeth extremely tall, with large accessory columns in the upper true molars, and their valleys filled up by a large quantity of cement. The horn-cores may be either rounded, flattened, or angulated, and are frequently directed more or less outwardly, but are never curved spirally inwards, or of the "cork-screw" shape characteristic of many Goats; while the horns themselves are not marked on their anterior surface by prominent transverse ridges. The most aberrant genus is *Leptobos* from the Pliocene and Pleistocene of India and the Upper Pliocene of Italy, in which the frontal portion is broad, with widely separated horn-cores placed far below the level of the occiput. The horn-cores are sometimes absent; and this genus is regarded as allied to *Boselaphus*. *Bubalus*, typically represented by the Buffaloes of India and Africa, but which may also be taken to include the diminutive Anoa (*B. depressicornis*) of Celebes, is characterised by its angulated horn-cores, which may be directed either outwards or upwards, and by the great convexity of the forehead in the more typical forms. Among the more aberrant species may be reckoned three from the Siwalik Hills of India (*e.g.*, *B. occipitalis*), which are closely allied to the Anoa, and (together with that species) by some writers are termed *Probubalus*; the horn-cores are frequently completely triangular in section, and the forehead is not decidedly convex. *B. platyceros* from the same deposits is intermediate between the last-mentioned group and the existing Buffaloes. *B. antiquus* from the Pleistocene of Algeria is regarded by Professor Rütimeyer as closely

allied to the existing African Buffaloes, although Dr P. Thomas thinks it is more nearly related to the living Indian species. The latter (*B. buffelus*) is found in a fossil state in the Pleistocene of the Narbada Valley, India; while an apparently closely allied form also occurs in the Pliocene of the Siwalik Hills. In *Bison*, now represented by the Aurochs of Lithuania (*B. bonasus*) and the nearly exterminated North American *Bison americanus*, the skull is characterised by its great relative width and shortness, the tubular orbits, the moderately convex forehead, and the curved, round, horn-cores, which are placed considerably below the level of the occiput. The existing European species is represented by a variety (*priscus*) in the Pleistocene of Europe and Arctic America; while the gigantic *B. latifrons* of the Pleistocene of Texas may probably be looked upon as the progenitor of the recent species of that country. A cranium from the Pliocene of the Siwalik Hills has been referred to this genus with the name of *B. sivalensis*, and appears to be allied to existing forms. The genus *Bos*, which is confined to the Old World, is the most specialised representative of this section, and may be divided into the *Bibovine* and *Taurine* groups. In the former are included the wild Oxen of India and Burma, which are characterised by



Fig. 1223.—Cranium of the Urus, *Bos taurus*, var. *primigenius*, Pleistocene. Much reduced.

the more or less flattened horn-cores, and by certain peculiarities in the form of the occipital region. The earliest representative of this group is *Bos etruscus* from the Upper Pliocene of the Continent, in which the horn-cores are placed very low down on the frontals; this species being considered to be nearly related to *B. banting* of Burma. A more imperfectly known member of this group is *B. palæogaurus* of the Pleistocene of India, which may turn out to be identical with

B. gaurus now living in the same regions. In the *Taurine* group the frontals (fig. 1223) are extremely elongated, and the horn-cores, which in the type species are rounded, are placed immediately over the occiput. To this group may be referred *B. planifrons* and *B. acutifrons* of the Pliocene of the Siwalik Hills; the latter being remarkable for its sharply angulated frontals and its enormous horn-cores, which have a pyriform section. Another member is *B. namadicus* of the Pleistocene of Central India, which presents some approximation to the *Bibovine* group; but the best known fossil Ox is the Urus of the European Pleistocene (fig. 1223), which appears to be only a larger form of the existing Ox (*Bos taurus*), and of which the descendants of wild races are still preserved in Chillingham and some other British parks. A still smaller race, whose remains have been found in the turbaries and fens of England, and have been described under the names of *B. longifrons* and *B. frontosus*, seems to be only a stunted variety of the same species, from which it is probable that the small cattle of Wales and Scotland have been derived.

Suborder 2.—Perissodactyla.—The characters possessed by this suborder in common with the Artiodactyla are noticed under that head. The distinctive features of the Perissodactyla are to be found in the truncated distal surface of the astragalus (fig. 1224); the circumstance that the third digit in both the fore and hind feet is symmetrical in itself, and larger than either of the others (fig. 1225); the presence (except in *Chalicotherium*) of a third trochanter to the femur (fig. 1226); and the non-articulation of the fibula with the calcaneum. Other characters very generally observable in this suborder are, that the whole of the series of cheek-teeth are in contact with one another; that the upper premolars are nearly or quite as complex as the true molars; that the last lower true molar frequently has no third lobe, and that when such third lobe is present, it is absent in the last lower milk-molar; while the first tooth of the cheek series is sometimes preceded by a milk-tooth. In all existing forms the number of the dorso-lumbar vertebræ is never less than twenty-two, and is usually twenty-three; while the nasals are expanded posteriorly. The stomach is simple, and the placenta diffused. In existing forms the cervical vertebræ are markedly opisthocœlous. The upper true molars are constructed on some modification of what is known as



Fig. 1224.—Anterior view of the left astragalus of the Horse (*Equus caballus*). One-half natural size.

the *Lophodont* plan (fig. 1228); that is, there is an outer longitudinal wall, from which two transverse ridges proceed at right angles towards the inner border of the crown. In the brachydont forms this structure is perfectly simple, but in those genera with very hypsodont teeth it is so complicated by foldings and involutions that it is not always easy to trace the original plan. The crowns of the lower true molars consist in their simplest structure of two transverse ridges (as in the Tapir), but these ridges may be curved into crescents (as in the Rhinoceros), or complicated by foldings

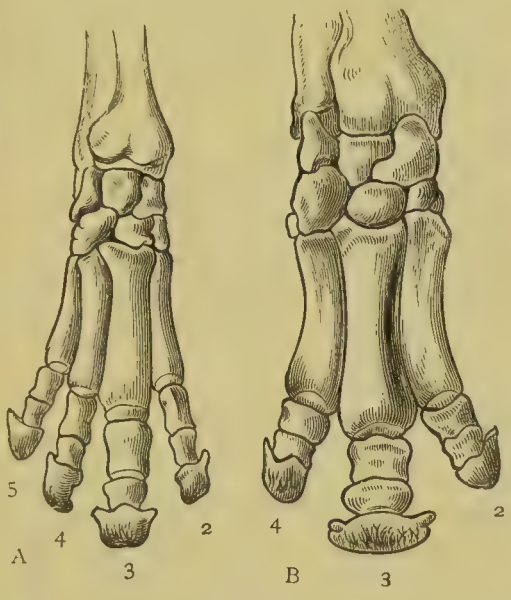


Fig. 1225.—Right manus of (A) *Tapirus*, and (B) *Rhinoceros*. Reduced. (After Flower.)



Fig. 1226.—Dorsal or anterior view of the left femur of *Rhinoceros*. The median projection on the right side of the figure is the third trochanter. Reduced.

and convolutions (as in the Horse). The transition from the simplest brachydont to the most specialised hypsodont dentition is accompanied by a reduction of the number of the digits from four or three to one; that one being the third, or middle, of the typical series of five.

The Perissodactyla have suffered considerably more in proportion to their numbers than the Artiodactyla by the extinction of generic and family types; the existing genera being at the present day reduced to three, which are the types of as many different families. Some writers have suggested that this extinction of types is owing to the Lophodont plan of molar structure being less readily suscep-

tible of modification than the Bunodont type upon which the Artiodactylate molar is constructed, but this is really a pure assumption.

Family Tapiridæ.—This family is represented by the single existing genus *Tapirus*, now found in the widely separated areas of the Malay Peninsula and South America, and thus affording an excellent example of what is termed discontinuous distribution. The dental formula is $I.\ \frac{3}{3}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{4}{3}$, $M.\ \frac{3}{3}$; the cheek-teeth are brachydont, and of the simple Lophodont type; the hinder premolars being as complex as the true molars, and the last lower molar having no third lobe. The first upper premolar has a deciduous predecessor; and in the existing forms there are four digits in the anterior (fig. 1225, A), and three in the hind foot. The cranium (fig. 1227) has its cerebral portion much vaulted, and the

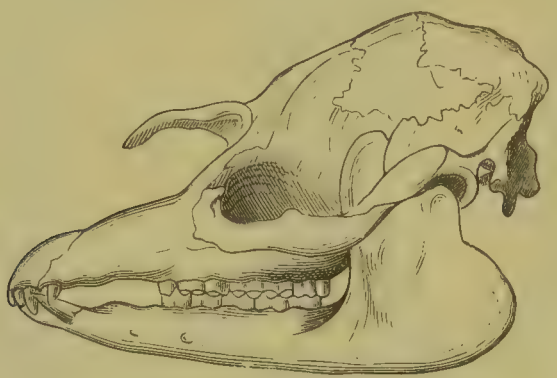


Fig. 1227.—Side view of the skull of *Tapirus americanus*. Reduced. (After Giebel.)

nasals short and arched; in one American species (which on this account is regarded by some authors as generically distinct under the name of *Elasmognathus*) the narial septum is largely ossified; and there is a short proboscis. In Europe this genus is found in the Middle Miocene of France (*T. Poirrieri*), and continues to the Upper Pliocene (*T. arvernensis*); it also occurs in the Pliocene of China (*T. sinensis*), and in the Pleistocene cave-deposits of Brazil, one of the forms from the latter being indistinguishable from the living *T. americanus*. The North American Miocene forms named *Tapiravus* are probably not generically distinct. An imperfectly known form from the Middle Eocene of France, described as *Palæotapirus*, is referred by Dr Filhol to this family.

Family Lophiodontidæ.—This Eocene family presents characters allying it very closely with the *Tapiridæ*, *Palæotheriidæ*, and *Rhinocerotidæ*, and probably contains ancestral forms of all those families. The upper true molars (fig. 1228) are brachydont, and always more complex than the premolars; the last lower true molar

generally has a third lobe; and there are usually four digits in the manus and three in the pes. The type genus *Lophiodon* (fig. 1228, A) comprises some species which attain a bulk rivalling that of the Rhinoceroses, and has the dental formula $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{3}{3}$, $M.\frac{3}{3}$. It is found in the Middle and Upper Eocene of Europe, and is generally regarded as having died out without descendants. In the dentition here figured the inner crescent of the fourth upper premolar is incomplete, and the ridges of the lower molars are simple; the last lower true molar always has a third lobe. Allied to *Lophiodon* is *Helaletes* (*Desmatotherium*), of the Upper Eocene of North America, characterised by the more rounded upper true molars and the absence of a diastema in the lower jaw; it is re-

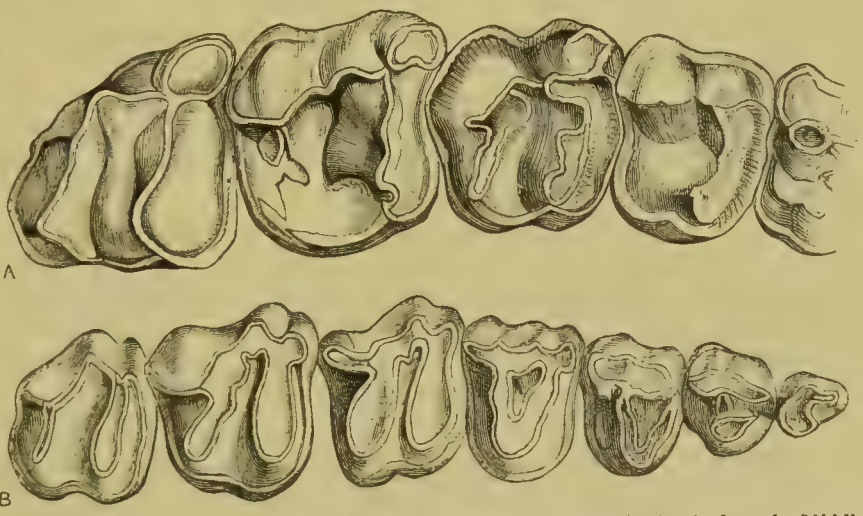


Fig. 1228.—A, The last five right upper cheek-teeth of *Lophiodon isselensis*, from the Middle Eocene of France; B, The right upper cheek-teeth of *Hyrachyus agrarius*, from the Eocene of North America. Reduced.

garded by Professor Cope as an ancestral stock of the *Rhinocerotidæ*. With forms from the North American Eocene described as *Isectolophus* and *Prothyracodon*, in the first of which the last lower true molar has a third lobe, we come to the consideration of Lophiodonts showing more affinity with the Tapirs, but it does not appear quite certain that both these forms are really entitled to generic distinction from the next. The genus *Hyrachyus* (fig. 1228, B), which occurs typically in the Uinta and Bridger Eocene of the United States, is taken by Dr Filhol to include European Lophiodonts ranging from the Middle Eocene of France to the Lower Miocene of St Gérand-le-Puy. This genus has four premolars, of which the last is somewhat simpler than the first true molar; while there is no third lobe to the last lower true molar. In the type species the

upper true molars (fig. 1228, B) resemble those of the *Rhinocerotidæ;* but there appears to be a gradual transition in this respect towards *H. priscus*, of the Quercy Phosphorites, in which these teeth have rounded angles, and approximate to those of the Tapirs; from which, however, these forms are distinguished by the simpler fourth premolar. This transition has induced Dr Filhol to abolish the genus *Protapirus*, which was proposed for *H. priscus*. The latter species is evidently allied to the American *Isectolophus;* and Dr Filhol suggests a transition from this type towards the Tapirs. The typical American species of *Hyrachyus* is regarded as the ancestor of the genus *Hyracodon*, which is classed in the *Rhinocerotidæ*. An American species which may be provisionally included in *Hyrachyus* is said to have an attachment for a dermal horn on each nasal, on which account it is separated by Professor Marsh as *Colonoceros*. The American Eocene genus *Dilophodon* appears to be allied to this group.

The imperfectly known genus *Ribodon*, from the infra-Pampean beds of Patagonia, is apparently nearly allied to *Hyrachyus*. The genus *Triplopus*, of the Upper Eocene of the United States, is distinguished by having only three digits in the manus, on which account Professor Cope makes it the type of the family *Triplopodidæ*. In *Hyracotherium*, with which the forms described under the names of *Pliolophus* and *Orohippus*, and not improbably *Eohippus*, are identical, the upper true molars resemble those of *Lophiodon*, but their anterior ridge is incomplete, and the transverse ridges of the lower cheek-teeth have a tendency to assume a crescent-shape. In this genus there is a diastema behind the first premolar, but in an allied form from the Lower Eocene of North America, which has been named *Systemodon*, all the teeth are in contact. The numerous species of *Hyracotherium* indicate animals not larger than a Fox; the dentition is of the full typical number, and the structure of the fore-foot is shown in fig. 1236, A. This genus occurs in the Lower Eocene[1] both of Europe and North America, and, as will be more fully noticed below, it is regarded as the ancestral stock of the *Equidæ*. *Heptodon*, from the Eocene of New Mexico, which was originally identified with *Pachynolophus*, appears to connect the latter with *Hyracotherium*, although it is placed by Professor Cope next to *Hyrachyus*. In *Pachynolophus* the dental formula is of the full typical number; but the upper true molars have taller ridges than in *Hyracotherium*, and are intermediate in structure between those of the latter and of *Anchilophus;* the lower molars being subcrescentoid. The largest species is *P. isselanus*, but there are

[1] It has recently been recorded from the Middle Eocene and the Phosphorites of France; but at least one of the species from the latter deposits indicates a form more nearly allied to *Anchilophus*.

several other forms from the Middle and Upper Eocene of the Continent; *Propalæotherium* (in which *Lophiotherium* may be included) does not appear generically separable.

Family Palæotheriidæ.—With the *Palæotheriidæ* we enter upon another extinct family of this suborder, the type genus of which has long been known from the classic labours of Cuvier. In this family the upper premolars may be either simpler or quite as complex as the true molars; the lower molars have crescentoid crowns, and in the last tooth of this series the third lobe may be either well developed or almost wanting; all the cheek-teeth are brachydont, and when cement is present it does not fill their valleys. There are always three digits in each foot. The type genus *Palæotherium*, in which may be included *Paloplotherium* (or *Plagiolophus*), ranges from the Middle Eocene of the Paris basin to the Lower Miocene of Ronzon, but is especially characteristic of the Parisian stage. The dental formula is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{(3-4)}{(3-4)}$, $M.\frac{3}{3}$; and the last lower molar has a third lobe. In the more typical species (fig. 1229) the four premolars are present in both jaws, the fourth upper pre-



Fig. 1229.—The right upper cheek-dentition of *Palæotherium crassum*; from the Upper Eocene of Paris. Reduced.

molar is as complex as the first true molar, and the third lower premolar as the fourth lower premolar; while the diastema is comparatively short, and the canines are not large. The upper true molars of all the species exhibit an expansion of the inner extremities of the transverse ridges, foreshadowing the structure of the teeth of some of the *Equidæ*. The cranium is Tapiroid in character, especially in the prominence of the nasal bones; from which it is deduced with great probability that the nose possessed a short movable proboscis. The general form may also be supposed to have been like that of the Tapirs, and the restoration of *P. magnum* given by Cuvier (fig. 1230) exhibits to us an animal closely similar to the existing Tapir. In this particular instance, however, we know that the restoration is incorrect, since the discovery of a complete skeleton of this species has shown that it was a more slender and longer-necked animal, resembling in its general figure a Llama.

In that group, which is considered by some writers as generically distinct under the name of *Paloplotherium*, the last upper premolar has its

hinder lobe more or less completely aborted, the third lower premolar is less complex than the fourth, the first lower premolar is absent, and the corresponding upper tooth may also be wanting; when the latter tooth is present it is sometimes preceded by a milk-molar. In this group *P. Javali*, from the Quercy Phosphorites, is remarkable for the presence of a considerable quantity of cement in the cheek-teeth, and for the approximation of the upper canine to the premolars and its apparent separation from the incisors. *P. minus* from the Paris basin is the smallest species

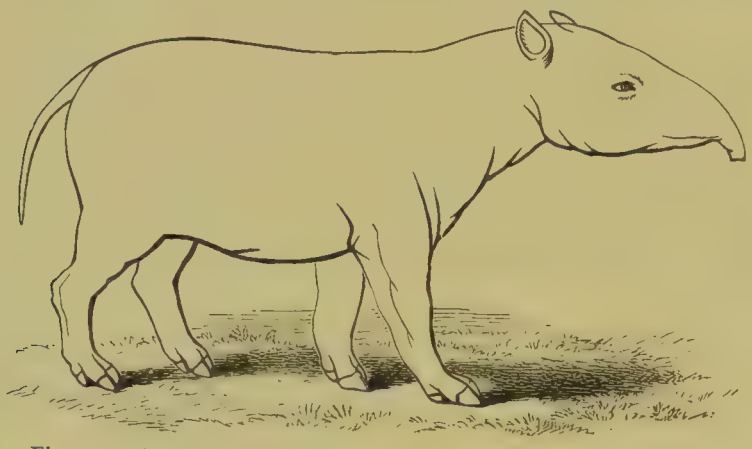


Fig. 1230.—Reduced restoration of *Palæotherium magnum*, after Cuvier. Upper Eocene, France.

of the genus; while *P. codiciense*, from the Middle Eocene of France, has its fourth upper premolar as simple as in *Lophiodon* and *Hyrachyus*, and thus shows how extremely intimate is the relation between all these early forms of the suborder, and how very difficult it is to give any good distinctive characters of the families into which it is convenient to divide them.

In *Anchilophus*, of the Upper Eocene of the Continent, the dental formula is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{?4}{3}$, $M.\frac{3}{3}$; and the cheek-teeth are nearly intermediate in structure between those of *Pachynolophus* and *Anchitherium*. The last upper premolar is as complex as the first true molar; there are well-marked ridges on the outer columns of the upper true molars; the last lower true molar has a large third lobe; and the diastema is elongated. The genus *Epihippus* from the Upper Eocene of North America, which is reckoned by some writers as being on the direct ancestry of the Horse, has been placed here by Dr Schlosser. The genus forming a step in advance of *Anchilophus* is *Anchitherium*, typically from the Middle Miocene of Europe, but with which the contemporary North American forms described under the names of *Mesohippus*



Fig. 1231. — A left upper true molar of *Anchitherium aurelianense*; from the Middle Miocene of France.

and *Miohippus* may be united. The dental formula is the typical one; the upper premolars are as complex as the true molars (fig. 1231), the external surface being without a median vertical ridge; the first lower premolar is comparatively small; and the third lobe of the last lower true molar is reduced to a small talon; while the incisors have no infolding of the enamel at their summits. Some species show a "larmial" depression in the lachrymal. The typical *A. aurelianense* (fig. 1231), of the Middle Miocene of the Continent, is the largest species, and shows no trace of the fifth metacarpal; while the meso- and entocuneiform of the tarsus are united. In the smaller *A. Bairdi* of the Miocene of North America the lateral digits are relatively larger, the fifth metacarpal is represented by a splint, and the meso- and entocuneiform are separate. Allied to this genus are *Anchippus*, *Parahippus*, and *Hyohippus* of the North American Miocene.

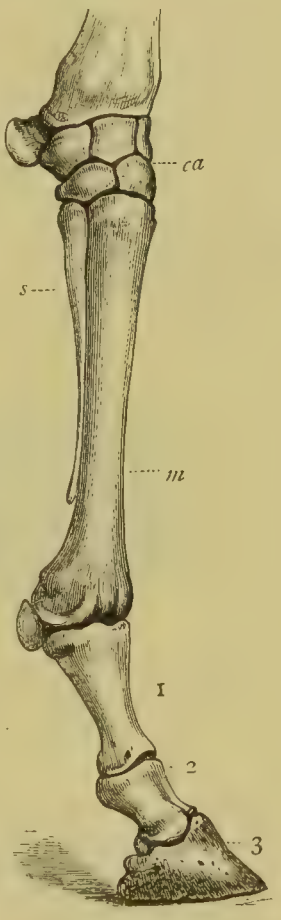


Fig. 1232.—Lateral view of the right manus of the Horse (*Equus caballus*). Reduced. *ca*, Carpus; *m*, 3d Metacarpal (cannon-bone); *s*, Lateral do.; 1, 2, 3, Phalangeals of third digit.

Family Proterotheriidæ.—In this place it may be convenient to notice the genus *Proterotherium* from the Tertiary of Patagonia, which was at first regarded by Dr Ameghino as belonging to the Artiodactyla, but was subsequently made the type of a distinct family of this suborder. One species was referred by Bravard to *Anoplotherium*, while a second was subsequently described by Dr Burmeister first as *Anchitherium*, and then as *Anisolophus*. The upper premolars are nearly as complex as the true molars. The names *Thoatherium*, *Diadophorus*, and *Licaphrium* have been applied to allied forms from the same deposits. The lower molars have four distinct roots. It may be questioned whether these forms are really entitled to form a distinct family.

Family Equidæ.—The division between this family and the *Palæotheriidæ* is a more or less arbitrary one. In the present one the upper premolars are as complex as the true molars, and all the cheek-teeth are usually of an extremely hypsodont type, with their valleys filled with cement; the crowns of the lower molars are crescentoid, with complex folds of enamel, and there is scarcely any distinct third lobe to the last lower molar. The digits may be

either one (fig. 1232) or three in number; the ulna and fibula are incomplete; and the meso- and entocuneiform of the tarsus are united. The plane of wear of the cheek-teeth becomes nearly smooth, instead of being raised into ridges as in the preceding families; and the summits of the incisors have an infolding of the enamel extending some distance into the crown. One of the most generalised forms is *Protohippus* or *Merychippus* of the Lower Pliocene of North America, in which the permanent molars resemble those of the generalised species of *Equus*, but have shorter crowns, while the milk-molars approximate more nearly to the true molars of *Anchitherium*. The next genus is *Hipparion* (*Hippotherium*). The dentition is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{3}$, $M.\frac{3}{3}$; but the first upper cheek-tooth, which has no predecessor and appears with the milk series, is shed before the animal is adult. The upper cheek-teeth (fig. 1233) at first sight seem to differ very widely



Fig. 1233.—Three right upper cheek-teeth of *Hipparion*; from the Pliocene of India. *a*, Posterior, and *b*, Anterior outer crescent; *c*, Anterior, and *d*, Anterior inner crescent; *e*, Anterior, and *f*, Posterior pillar.

from those of the *Palæotherium* type (fig. 1229), but a closer examination will show that the outer portions marked *a* and *b* correspond to the outer wall of the more generalised tooth; while the portions *c* and *e*, and *d* and *f* respectively represent the first and second transverse ridges of the same. These ridges have, however, united together in a crescent-like form, and enclose between them and the outer wall a pair of islands surrounded by a plicated wall of enamel and filled with cement. The terms which it is convenient to apply to the Equine molar are indicated in the accompanying figure; and the distinctive feature of the upper teeth of *Hipparion* is that the anterior pillar (*e*) is disconnected from the anterior inner crescent (*c*) for at least three-quarters of its height, so that it normally appears on the worn crown as an isolated oval (fig. 1233). There are normally three digits to each foot, but in the Pliocene Indian *H. antilopinum* they are apparently reduced to one; this

form having been made the type of the genus *Hippodactylus*. The best known species is *H. gracile* of the Pliocene of Europe, Samos, Persia, and Algeria; but the genus is also well represented in the Pliocene of India (*H. antilopinum*, *H. Theobaldi*), China (*H. Richthofeni*), and North America. All the species retain the primitive feature of a depression in the lachrymal. With *Equus* (in which may be included the American *Hippidium*, otherwise *Pliohippus*) we come to the most specialised of all the Perissodactyla. The dentition is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{(3-4)}{(3-4)}$, $M.\frac{3}{3}$; but the first upper cheek-tooth is usually absent in existing forms, and the corresponding lower one is only occasionally developed in some extinct species. The crowns of the cheek-teeth are higher than in *Hipparion*, and the anterior inner pillar of the upper ones, except in a very early stage of wear, is connected with the adjacent inner crescent (fig. 1234). There is but one functional digit to each foot, although the

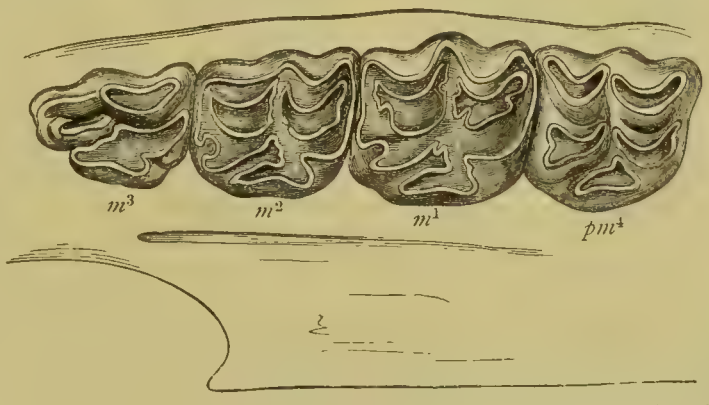


Fig. 1234.—The last four right upper cheek-teeth of the Horse (*Equus caballus*). Reduced.

proximal portions of the lateral metapodials remain (figs. 1232, 1236, D), and in the so-called *Hippidium* the terminal phalangeals were represented by claws. A maxillo-lachrymal fossa is present in the extinct *E. andium* and *E. sivalensis*, but is wanting in all existing species. At the present day this genus is confined to the Old World, and is especially characteristic of Africa, but in the Pliocene and Pleistocene it was spread over both North and South America.

In those South American Pleistocene forms referred by some writers to *Hippidium*, the molars are shorter and more curved than in existing species, and the grinding surface of the anterior pillar of the upper ones is not wider than in *Hipparion*; *E. principalis* is a large species of this type. In *E. Stenonis* of the Upper Pliocene of Italy, Kos, and Algeria, and the Norfolk Forest-bed, the molars are taller, but they still

have a narrow anterior pillar in the upper jaw, and thus show their connection with *Hipparion*. In *E. sivalensis*, of the Pliocene of India, and *E. quaggoides* of that of Italy, this pillar becomes rather more widened; and in the Pleistocene *E. namadicus* of India, as well as in *E. curvidens* of that of Brazil, and all the existing members of the genus (fig. 1234) the grinding surface of this pillar becomes greatly widened in the antero-posterior direction. It is noteworthy that *E. sivalensis* is found in the same beds as those containing *Hipparion;* and that the existing *E. caballus* is apparently the common species of the European Pleistocene, although it is not improbable that the Asiatic *E. onager* may also occur in the same deposits. In Southern India, where no living species are found, the remains of the existing African *E. asinus* and of a larger



Fig. 1235.—Skull of the Horse (*Equus caballus*). Reduced.

undetermined form occur in the Pleistocene cave-deposits of Madras. Finally, it should be mentioned that some of the South American Tertiary forms have been separated under the name of *Haplohippus*.

Genealogy of the Horse.—Allusion has been incidentally made in the preceding paragraphs to the genealogy of the genus *Equus*, but since this is one of the best instances of evolution among the higher Mammals yet worked out it is advisable that it should be noticed rather more fully. The top of the series is the *Equus caballus* group, in which the dentition is of the most specialised type, and which descends in India to the topmost Pliocene; then we have the *E. Stenonis* and *E. principalis* group, in which the molars become more like those of *Hipparion;* and finally the so-called *Hippidium*. The structure of the foot is shown in fig. 1236, D; the great size of the phalangeals and the metapodial of the functional digit being very noticeable. The earliest occurrence of the genus is in the Pliocene of India. From the *E. Stenonis* group to *Hipparion* is but a step, the transitional species being *H. antilopinum* of the Pliocene of the Siwalik Hills in which the lateral digits were apparently wanting; in the other species (fig. 1236, C) the lateral digits are of small size, and the middle one is relatively more slender than in *Equus*. *Protohippus* connects *Equus* by the structure of its milk-molars with the Miocene *Anchitherium:* and in the latter the teeth have become brachydont, the third lower molar has a small third lobe, and the lateral

digits of the foot (fig. 1236, B) have become larger and the middle digit smaller; traces of the fifth metacarpal being retained in the American species. The next step is probably made by some form allied to *Anchilophus* or *Pachynolophus* of the Upper Eocene; and from such a type the transition is easy to the Lower Eocene *Hyracotherium* and *Systemodon*, in which all the species are very small, the dentition is of the simple Lophodont type, with a large third lobe to the last lower true molar, and the fore-foot (fig. 1236, A) has four complete digits, which are of subequal size; while there may be (*Eohippus*) a rudimental metacarpal of the pollex. Finally, the earliest stage of this series is formed by *Phenacodus* of the Lowest or Puerco Eocene of North America, in which there are five digits to each foot, and of which the structure will be more fully noticed under the head of the suborder Condylarthra. It should be observed, however, that Professor Cope would introduce an inter-

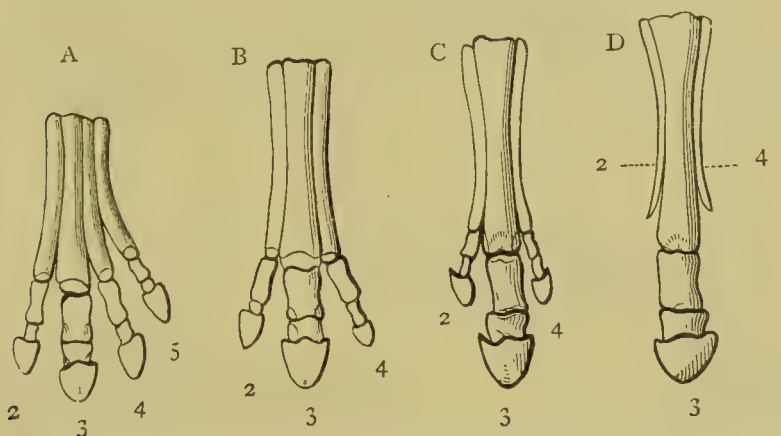


Fig. 1236.—Bones of the left manus of *Hyracotherium* (A), *Anchitherium* (B), *Hipparion* (C), and *Equus* (D).

mediate stage between *Systemodon* and *Phenacodus;* and that the same authority also introduces the genus *Palæotherium* between *Hyracotherium* and *Anchitherium*, although most writers regard that genus as quite off the line.

In this connection may be noticed the remarkable circumstance that in the line of evolution culminating in the modern Horse a parallel series of generically identical or closely allied forms occurs in the Tertiaries of both Europe and North America, from which it has been suggested that in both Continents a parallel development of the same genera has simultaneously taken place—*i.e.*, that in both regions *Anchitherium* has given rise to *Hipparion*, and *Hipparion* or an allied type to *Equus*. Now, seeing it is evident that in the case of species of a single genus the evolution has taken place in separate lines.—that is to say, that the existing Indian species of *Canis* are probably derived directly from the Pliocene forms of the same region, and the Brazilian species of that genus have their predecessors of the cave-epoch of that country,—there appears no logical reason for refusing to admit an analogous parallel evolution in the case of genera, and there is accordingly a considerable probability that the hypothesis in question may be a true one. Professor Cope considers that in one country *Protohippus*, and in the other *Hipparion*, was the immediate ancestor of *Equus*.

Family Rhinocerotidæ.—With this family we enter upon the consideration of another branch probably derived from the primitive Lophiodont stock, which attained great development in Tertiary times, and is still represented in Asia and Africa by at least five well-defined species. It is not easy to distinguish this family from the *Lophiodontidæ*, as represented by *Hyrachyus* (which Dr

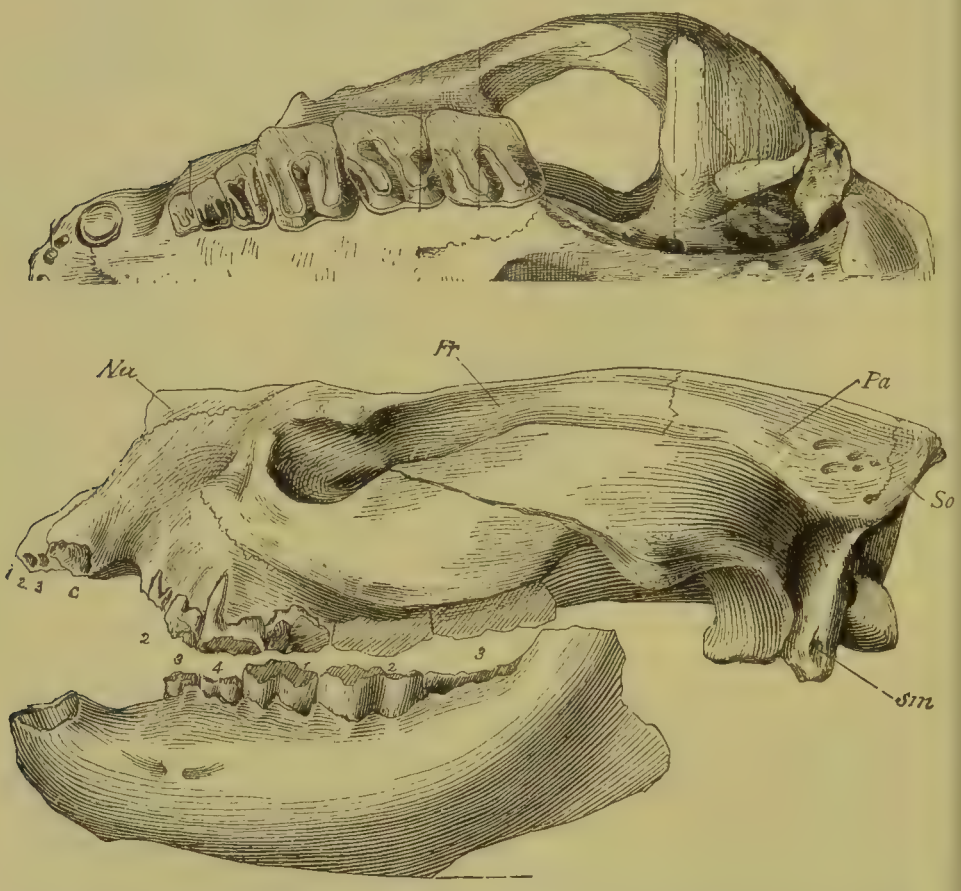


Fig. 1237.—Left half of the palatal surface of the cranium, and left lateral aspect of the skull of *Metamynodon planifrons;* from the White River Miocene of North America. One-sixth natural size. *Na*, Nasal; *Fr*, Frontal; *Pa*, Parietal; *So*, Supraoccipital; *sm*, United postglenoid and posttympanic processes; 1, 2, 3, Alveoli of incisors; *c*, Alveolus of canine; 2, 3, 4, Premolars; 1, 2, 3, True molars. (After Scott and Osborn.)

Schlosser includes in the *Rhinocerotidæ*), but the upper true molars (fig. 1239) generally have a very thick outer wall, which is often produced in advance of the first ridge; their transverse ridges are but slightly bent, and are intimately connected with the outer wall; the upper premolars are usually nearly or quite as complex as the true molars; the lower cheek-teeth are more or less completely

crescentoid; and in all the forms in which that tooth is known there is no third lobe to the last lower true molar. The height of the cheek-teeth varies considerably, their crowns being tallest in *Elasmotherium*. One or more dermal horns may be attached to the fronto-nasal region; and when two of these appendages are present they may be either placed one behind another in the middle line, or in a pair on either side of this line. The digits of the pes are apparently always three, but there may be either three or four in the manus. One of the most generalised forms is *Hyracodon*, from the Lower Miocene of Nebraska, in which the dental formula is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{4}$, $M.\frac{3}{3}$. There were apparently only three digits; the neck and limbs were slender and Horse-like; and there was no trace of a nasal horn. This genus was in all probability a descendant of the Lophiodont *Hyrachyus*, but does not appear to have been the progenitor of the true Rhinoceroses. In some respects still more generalised is the genus *Amynodon* (*Orthocynodon*), from the Middle and Upper Eocene of North America, in which the dental formula was the same as in *Hyracodon*. The lower canines were nearly upright; there was a short diastema; the premolars were unlike the true molars; and it is believed that the manus had four digits. Allied to this genus is *Metamynodon*, from the Miocene of the United States, in which the skull (fig. 1237) has a strong sagittal crest, the premolars are reduced to $\frac{3}{2}$, the lower canines have become somewhat proclivous, and the upper premolars are much more like the true molars. These two genera are regarded by some of the American palæontologists as indicating a distinct family—the *Amynodontidæ* — and are also looked upon as the ancestors of the true Rhinoceroses. In the Old World there is, however, the genus *Cadurcotherium* of the Quercy Phosphorites, which may possibly lay claim to this position, although it may indicate a lateral branch allied to the Toxodontia. Unfortunately, only detached teeth are at present known, so that the dental formula cannot be determined. The upper true molars (fig. 1238)

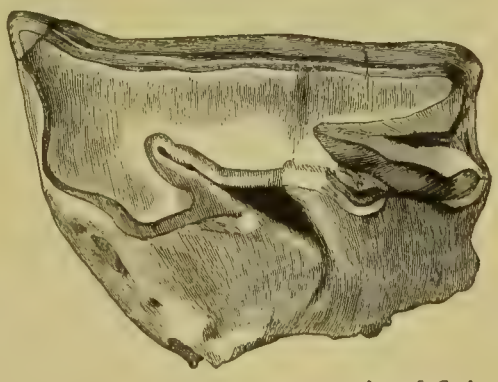


Fig. 1238. — A left upper true molar of *Cadurcotherium cayluxense*; from the Upper Eocene of France.

are Rhinocerotic in structure, but are extremely narrow in a transverse direction, and the ridges of the lower cheek-teeth are imperfectly crescentoid. Apparently nearly related to the preceding is *Homalodontotherium*, from Tertiary strata of unknown age in Patagonia; the dental formula is the typical one, and there is no diastema, but the skeleton is unknown. We now come to the consideration of those animals which we may term true Rhinoceroses—a group in which very diverse views as to the limits of generic terms are prevalent among zoologists and palæontologists. By some writers the five existing species are referred to at least three distinct genera, and if this view be adopted, it will be necessary to make a large number of genera for the extinct forms; the English school, however, now generally include all the living species in one genus, and from this point of view there seems no good reasons for generically separating any of the extinct species, which form a series so intimately connected that it would be very difficult to define all the genera into which they are divided by the American school.[1] Using, then, the term *Rhinoceros* in its widest sense, the variations in the number of teeth may be expressed by the formula $I.\ \frac{(0-2)}{(0-1)}$, $C.\ \frac{0}{(0-1)}$, $Pm.\ \frac{4}{4}$, $M.\ \frac{3}{3}$; the absence of upper canines is a distinctive feature; the upper true molars (fig. 1239) have their crowns relatively wide, their transverse ridges well developed, the hinder lobe of the last

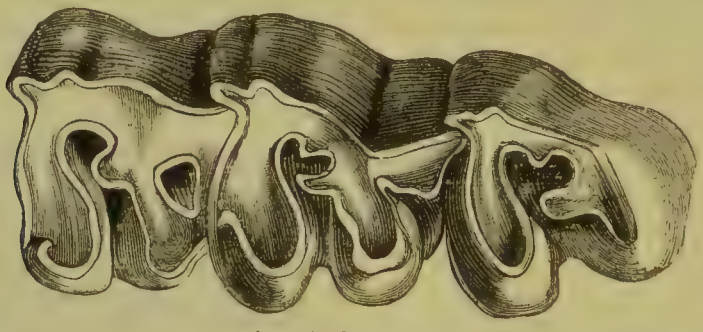


Fig. 1239.—The left upper true molars of *Rhinoceros megarhinus;* from the Pleistocene of England. One-half natural size.

tooth partially aborted, and frequently a more or less distinct buttress at their antero-external angle. The teeth represented in fig. 1239 are the most generalised type; and it is evident that, when more

[1] In this and other instances the number of generic divisions which we may be disposed to adopt is solely a matter of convenience. From the writer's point of view the multiplication of generic terms, which as our knowledge advances must become less and less susceptible of exact definition, tends to drown the science in a sea of names, which form a great burden to the memory, and thus tend to destroy the very object of classification.

worn, the crown of each molar would carry two isolated fossettes surrounded by enamel (fig. 1244). The worn crown-surface is transversely ridged; and there is a process projecting from the hinder ridge into the middle valley termed the crochet, which is absent in some species. The hinder premolars are as complex as the true molars; and the crowns of the cheek-teeth, though varying in height, are never very tall, and their valleys are always open. In the lower cheek-teeth the ridges form complete crescents, with their concavity directed inwardly (fig. 1240). The lower canines are always proclivous. The skeleton and skull are very massive, this feature being most marked in the more specialised species. This genus may be divided into several groups, of which the *Aceratherine* is the most generalised. In this group there is usually no horn, and the nasal bones (fig. 1241) are consequently small; cutting-teeth are always present, although there is some variation in their number, which may be expressed by the formula $I.\frac{(0-2)}{1}$, $C.\frac{0}{1}$. In *R. incisivus* (which is the type of the so-called *Aceratherium*) there are four digits in the manus; but in many of the North American forms (which on this account are separated by

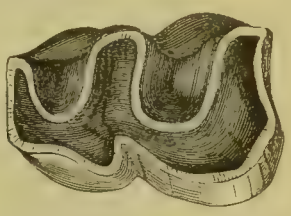


Fig. 1240.—The third left lower true molar of *Rhinoceros megarhinus;* Pleistocene. Two-thirds natural size.

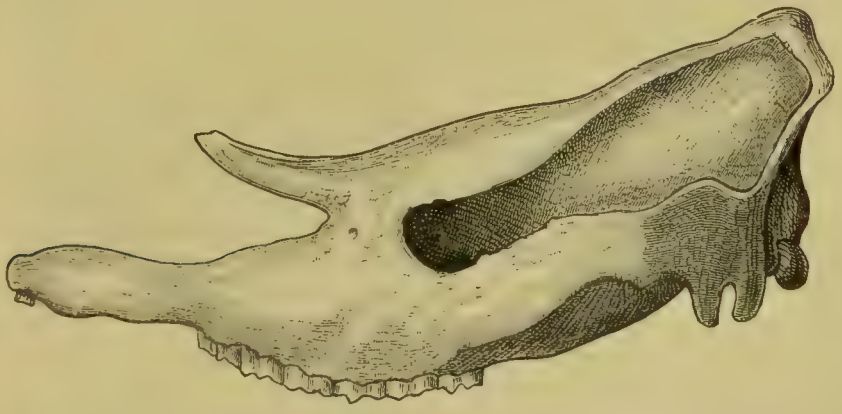


Fig. 1241.—Cranium of *Rhinoceros incisivus;* from the Lower Pliocene of Germany. One-seventh natural size. (After Kaup.)

Professor Cope under the name *Aphelops*, fig. 1242) the number of digits was reduced to three; and these forms were thus similar to some female examples of the existing *R. sondaicus*, in which the horn is absent. In Europe this group ranges from the Lower Mio-

cene to the Lower Pliocene; it also occurs in the Upper Miocene and Pliocene of India, and in the Upper Miocene (or ? Pliocene) of North America. In the *Diceratherine* group (*Diceratherium* of



Fig. 1242.—Skull of *Rhinoceros megalodus;* from the Upper Miocene of Colorado. One-sixth natural size. (After Cope.)

Marsh) there was a transversely-placed pair of small nasal horns; the formula of the cheek-teeth being $I.\ \frac{1}{1}$, $C.\ \frac{0}{1}$: it is represented in the Lower Miocene of Europe by *R. minutus*, and by another species in North America. At this stage of evolution the genus disappeared from the latter country.

The *Rhinocerotine* group is characterised by the presence of a single well-developed nasal horn,[1] and of cutting-teeth in both jaws. It is represented at the present day by the Asiatic *R. sondaicus* and *R. unicornis* (fig. 1243), the upper true molars of the former being of the type of those of *R. megarhinus* (fig. 1239), while those of the latter are of the more specialised type of *R. antiquitatis* (fig. 1245). The ancestor of *R. sondaicus* is probably to be found in *R. sivalensis*, of the Pliocene of India; while *R. palæindicus* appears to be the species from which *R. unicornis* has sprung. The *Ceratorhine* group, represented by the existing Asiatic *R. sumatrensis*, and the European Lower Pliocene *R. Schleiermacheri*, differs from the preceding by having two horns, placed one behind the other in the median line, but still retains cutting-teeth in both jaws; the upper

[1] The horn of the Rhinoceroses, it should be observed, consists merely of a bundle of closely agglomerated bristles, and has no bony attachment to the skull.

molars in both species being of the type of fig. 1239. This group cannot probably be separated from the next, with which it is connected by *R. persiæ*, of the Pliocene of Maragha in Persia, which had lower canines, although apparently allied to *R. platyrhinus*. The most specialised, or *Atelodine*, group is represented at the

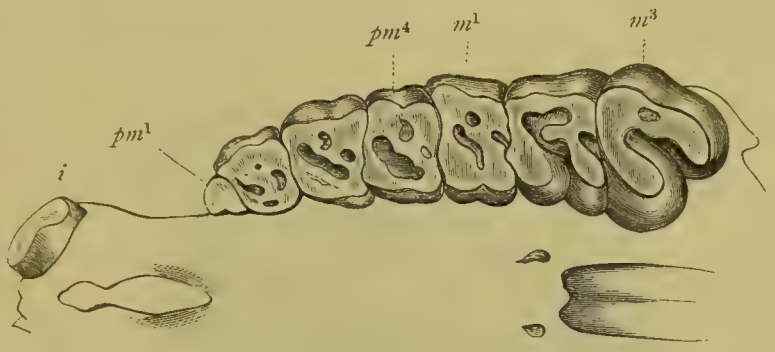


Fig. 1243.—Worn left upper dentition of *Rhinoceros unicornis*; India. Much reduced. (After Cuvier.)

present day by the African *R. simus* and *R. bicornis*, in which there are two large horns, but no cutting-teeth in either jaw. Of species with upper molars of the simpler type of fig. 1239, we may mention *R. pachygnathus*, of the Lower Pliocene of Greece and the isle of Samos, which is closely allied to the African *R. bicornis*; *R. etruscus* (fig. 1244), of the Upper Pliocene of Europe (in which

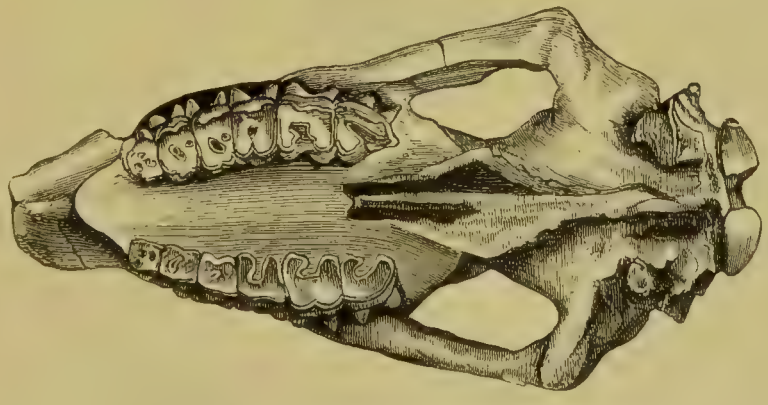


Fig. 1244.—Palatal view of the cranium of *Rhinoceros etruscus*, with the teeth much worn; Upper Pliocene, Italy. One-seventh natural size.

the molars are of a brachydont structure); *R. deccanensis* and *R. karnuliensis*, of the Pleistocene of Southern India; and *R. megarhinus* (fig. 1239) and *R. leptorhinus*, of the European Pleistocene. In the latter there is an ossification of the nasal septum. The other members of this group have their upper molars (fig. 1245) of

a more complex type; there being an absence of a buttress at the antero-external angle, and the folds of the crown so arranged that when more worn than in the figured specimen three islands of enamel would be formed on their crowns. These teeth are also characterised by their plane of wear being perfectly horizontal, and by their relatively tall crowns. An early member of this type is *R. platyrhinus*, of the Pliocene of Northern India; from which species



Fig. 1245.—The second right upper true molar of *Rhinoceros antiquitatis*; from the Pleistocene of Kent.

it is highly probable that both the existing African *R. simus*, and the Pleistocene *R. antiquitatis*, of Northern Asia and Europe, have been derived.

The latter species, of which the skull is represented in fig. 1246 and an upper molar in fig. 1245, is sometimes known as the Woolly Rhinoceros, since it was covered with a thick coat of woolly hair. The skin was devoid of the folds which characterise the large Indian species; and the front horn was of very large size. As in some of the Pleistocene species the septum of the nares was completely ossified (fig. 1246). This species is essentially a northern form, and has nearly the same distribution as the Mammoth, although it does not appear to have crossed Behring Strait into America. In time this Rhinoceros makes its first appearance in the Pleistocene Brick-earths of the Thames valley, and is very common in European cave-deposits, and in the *tundras* of Siberia. Complete carcasses, still covered with the dried flesh, skin, and hair, have not unfrequently been found washed out from the frozen alluvial deposits of these *tundras* on the banks of the Yenesi and Lena; from which we learn that

the food of this animal mainly consisted of the leaves and twigs of juniper and other coniferous plants.

The last representative of this family is the gigantic *Elasmotherium* (*Stereoceros*) of the Pleistocene of Siberia, in which the dental formula of the adult is $I.\ \frac{0}{0}$, $C.\ \frac{0}{0}$, $Pm.\ \frac{2}{2}$, $M.\ \frac{3}{3}$. The structure of the skull and limbs is essentially Rhinocerotic; and in the former the narial septum was completely ossified, and the frontals have a huge bony protuberance for the support of a large horn corresponding to the second one of *Rhinoceros antiquitatis*. The teeth differ considerably from those of any species of *Rhinoceros*,

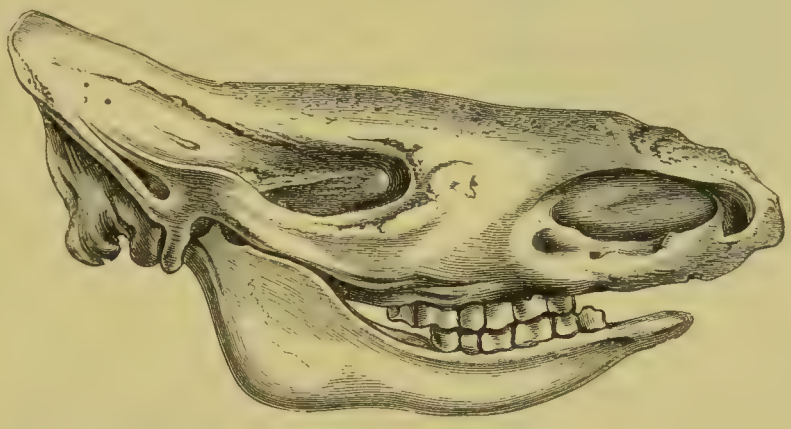


Fig. 1246.—Right lateral aspect of the skull of a young individual of *Rhinoceros antiquitatis*; from the Pleistocene of Siberia. Reduced.

and are characterised by their very tall crowns, plicated enamel, and smooth plane of wear. Their structure is, however, merely an extreme modification of the Rhinocerotic type, to which the nearest approach among later forms is made by *R. antiquitatis*. There is, however, in these teeth a marked resemblance to those of *Caduro-therium* and *Homalodontotherium*, and it is not improbable that *Elasmotherium* presents the last representative of a stock descended from the former genus which has remained altogether apart from the true Rhinoceroses.

Family Lambdotheriidæ.—With the *Lambdotheriidæ* we enter upon the consideration of the first of three extinct families in which the cheek-teeth have remarkably short (brachydont) crowns, and diverge to a certain extent from the more typical Lophodont form. The upper true molars (fig. 1247) may be described as consisting of four columns, of which the two hindmost are frequently connected by an oblique transverse ridge; while there may also be a more incomplete anterior ridge. When these teeth are worn two

V-shaped surfaces of dentine appear on the crown. This type of tooth may be derived from the Lophodont by the more or less complete abortion of the middle portions of the transverse ridges. The upper premolars are simpler than the true molars, and have but a single inner column; while the lower cheek-teeth are crescentoid, the last true molar usually not having a complete third lobe. There was always a diastema in the dental series, and the skull was devoid of bony protuberances. In the present North American family the femur has a third trochanter, and the feet are of the normal Perissodactylate type, the manus being provided with four, and the pes with three digits. This family is represented by *Palæosyops* and *Limnotherium*, from the Upper Eocene, in which there are four premolars, and the last lower true molar has a third lobe; the canines being large and resembling those of the Carnivora. *Lambdotherium* is another form of later age; while in the White-river Miocene of Canada we have *Haplacodon*, with only two pairs of lower incisors.



Fig. 1247.—The third right upper true molar of *Chalicotherium sinense;* from the Pliocene of China.

Family Chalicotheriidæ. — The second family, or *Chalicotheriidæ*, is found in both the Old and the New Worlds, and presents such a remarkable abnormality in the structure of the feet, as to render it for the future quite unsafe to predict the character of an animal from a single bone, and to make invalid the old maxim *ex ungue leonem*. In the femur the third trochanter has been lost; and in the feet, while the proximal bones retain their normal Perissodactylate character, the phalangeals have been modified to resemble those of Edentates, the second phalangeal (fig. 1248) having a strongly developed distal trochlea for the articulation of the huge claw forming the terminal joint. These phalangeals have been described under the names of *Macrotherium* and *Ancylotherium*, and were until quite recently, when they were found by Dr Filhol in association with the skull and the rest

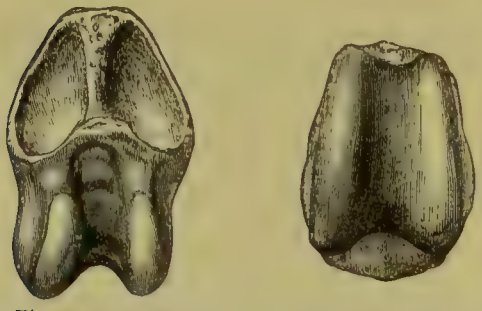


Fig. 1248.—Anterior and distal aspects of a second phalangeal of *Chalicotherium sivalense;* from the Siwaliks.

of the skeleton of *Chalicotherium*, thought to belong to huge Edentates. The latter writer has indeed proposed to regard this genus as a veritable Edentate, but the resemblance of its dentition to that of *Palæosyops*, coupled with the essentially Perissodactylate characters of the rest of the skeleton — notably the opisthocœlous cervical vertebræ — prevents the acceptation of this view, and compels us to regard this strange animal as a highly modified and aberrant Ungulate.[1] In the type genus *Chalicotherium*, with which *Macrotherium* is identical, there were variations in the number of the cutting-teeth analogous to those obtaining in *Rhinoceros*, which may be expressed by the formula $I.\ \frac{(0-3)}{(0-3)}$, $C.\ \frac{(0-1)}{1}$, $Pm.\ \frac{3}{3}$, $M.\ \frac{3}{3}$. The type species, which should be known as *C. giganteum*, occurs typically in the Lower Pliocene of Eppelsheim in Hessen-Darmstadt, and also in the Middle Miocene of Sansan in Gers; the claws were first described by Cuvier under the name of *Pangolin gigantesque*, and were subsequently made the type of the genus *Macrotherium*. Another species, *C. modicum*, occurs in the Upper Eocene Phosphorites of France, to which probably belong some large claws described as those of an Edentate. The genus also occurs in the Pliocene of China and India; the species from the latter area having been referred by Kaup to a distinct genus *Nestoritherium*, on account of the absence of the anterior teeth. The phalangeal from the Pliocene of Sind represented in fig. 1248 doubtless belongs to a small individual of this species, although first described as *Manis*, and subsequently as *Macrotherium*. It has likewise been lately recorded from the White-river Miocene of Canada and the Loup-Fork beds of Kansas. The last lower molar of *Chalicotherium* has no third lobe. From the Lower Pliocene of Attica the genus *Leptodon*, described on the evidence of a lower jaw with a Chalicotheroid dentition, but with a third lobe to the last molar, is probably identical with *Ancylotherium*, founded upon the evidence of claws from the same beds, which are of the same general type as those of the so-called *Macrotherium*. *Ancylotherium* also occurs in the Lower Pliocene of the isle of Samos. *Leptodon* has been provisionally referred by Dr Schlosser to the next family. *Moropus*, from the Loup-Fork of Kansas, and *Morotherium*, from the Miocene of the United States, which were described by Professor Marsh as Edentates, are probably closely allied to, if not identical with, either *Chalicotherium* or *Ancylotherium*. Finally, the imperfectly known *Brachydiastematotherium*, from the Eocene of Hungary, is probably

[1] Professor Cope has recently proposed to make *Chalicotherium* the type of a distinct order under the name of Ancylopoda.

referable to the present family, which is evidently a very ancient branch of the suborder, and may, it is suggested, have been directly derived from the Condylarthra.

Family Titanotheriidæ.—This extinct family, equivalent to the *Brontotheriidæ* of Professor Marsh and the *Menodontidæ*[1] of several other writers, is so closely connected by *Diplacodon* with the *Lambdotheriidæ*, that Dr Schlosser has proposed to unite the two. In the present family at least the fourth upper premolar has two inner columns, and is thus as complex as the true molars; while in those forms of which the limbs are known there are four anterior and three posterior digits. The third trochanter of the femur is rudimentary. Paired bony protuberances may be present in the fronto-nasal region of the skull. In *Diplacodon*, of the Eocene of North America, only the fourth upper premolar is as complex as the true molar; the canines are as large as in *Palæosyops;* the incisors $\frac{(3)}{(3)}$ are small; and the skull has no bony protuberances.

The type genus *Titanotherium*, which Messrs Scott and Osborn consider should include *Menodus* (preoccupied), *Megacerops*, *Brontotherium*, *Diconodon*, and probably *Symborodon*, is confined to the

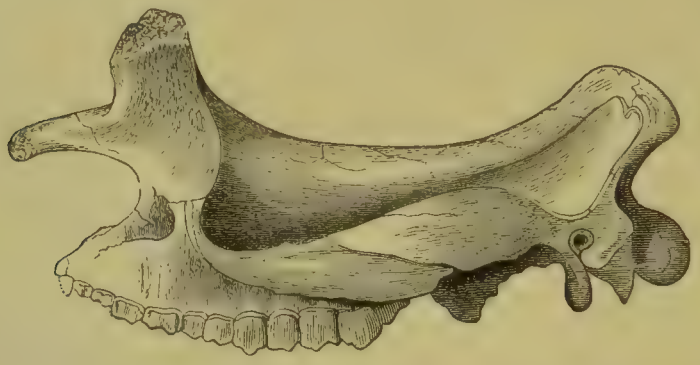


Fig. 1249.—Left lateral aspect of the cranium of *Titanotherium coloradense;* from the Miocene of North America. Greatly reduced. (After Marsh.)

Miocene of North America, and comprises animals of huge bulk; and it is probable that the forms recently described by Professor Marsh under the names of *Allops*, *Brontops* (fig. 1250), and *Menops* are not really separable. An entire skeleton is shown in fig. 1250, and a cranium in fig. 1249. The number of teeth is subject to a variation analogous to that obtaining in *Rhinoceros*, this variation being expressed by the formula $I.\frac{(2-3)}{(0-3)}$, $C.\frac{1}{1}$, $Pm.\frac{4}{(3-4)}$, $M.\frac{3}{3}$.

[1] The name *Menodus* is the earliest of those applied to these animals, but is inadmissible on account of the earlier application of *Menodon* to a fossil reptile.

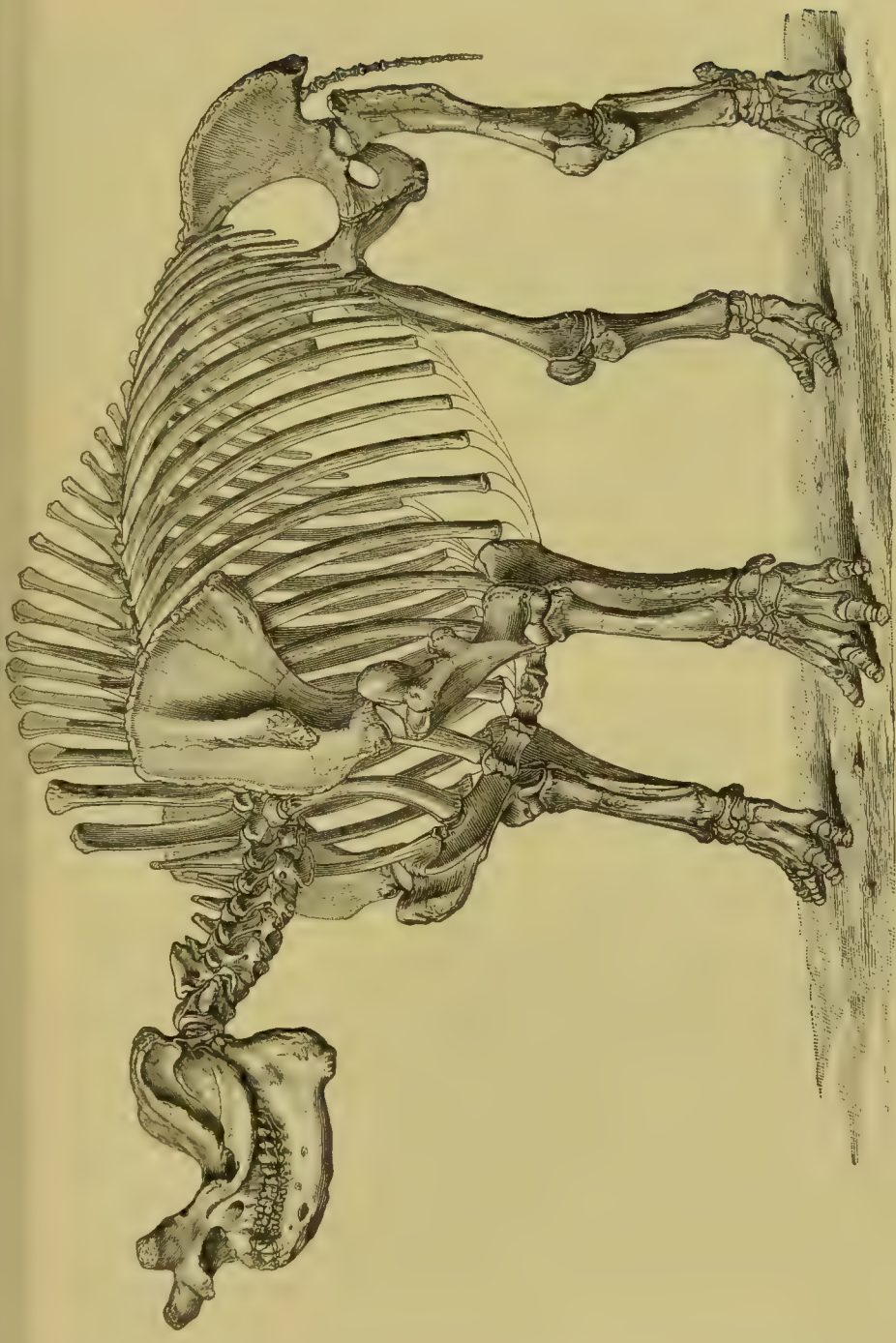


Fig. 1250.—Skeleton of *Titanotherium* (*Brontops*) *robustum*; from the Miocene of North America. $\frac{1}{14}$ natural size. (After Marsh.)

The molars and premolars are alike, the incisors are small, and in those species with a full dentition there is no diastema; while in the typical forms the canines are small. The cranium (fig. 1249) is

elongated, with a small brain-cavity, projecting nasals, and a pair of stout transversely placed prominences on the fronto-nasal region. A form to which the name *Dæodon* has been applied is distinguished by the larger canines. It has been suggested that the American *Meniscotherium* and the European *Hyracodontotherium* should be placed in this family.

Family Macraucheniidæ.—Here may be placed this remarkable family, which presents extremely generalised characters in the vertebræ and limb-bones, such as are unknown in any other members of the suborder, on which account some writers think it ought not to be included in the Perissodactyla. In the typical *Macrauchenia* from the Pleistocene of South America the dentition is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{4}$, $M.\frac{3}{3}$; the cheek-teeth are Rhinocerotine in structure, the upper molars showing two external V-shaped dentine surfaces and two transverse ridges; while there is only a very small diastema in the lower jaw. The cervical vertebræ resemble those of the *Camelidæ* in the position of their arterial canal. The fibula articulates with the calcaneum (as in the Artiodactyla), and there are three digits in each foot, of which the lateral ones are of large size. The incisors have a deep coronal infolding of the enamel, as in the *Equidæ;* and Dr Hermann Burmeister thinks that the muzzle was produced into a short proboscis. The type species is *M. patachonicha;* an allied form from the infra-Pampean beds of Argentina, named by Bravard *Palæotherium paranense*, is referred by Dr Burmeister to this genus, but has been made the type of a distinct genus by Dr Ameghino, under the name of *Scalibrinitherium Bravardi*. *M. minuta* from the same deposits is made by the latter writer the type of *Oxydontotherium;* and the name *Mesorhinus* is applied to yet another form from the same area. Here also may be noticed *Theosodon* from the above-mentioned deposits, which is placed by Dr Ameghino in this family, although it may be allied to *Homalodontotherium*, which is also placed here by that writer.

Suborder 3. Toxodontia.—This group includes a number of very aberrant and generalised Ungulates from the Tertiaries of South America, which present affinities to the Perissodactyla, Proboscidea, and Rodentia, and consequently render it almost impossible to draw up any distinctive diagnosis.

Family Toxodontidæ.—*Nesodon* from strata of unknown Tertiary age in *Patagonia* has its dental formula $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{4}$, $M.\frac{3}{3}$; the incisors having short crowns, and the true molars a complex Rhinoceroid structure, and thus connecting the dentition of *Macrauchenia* and *Homalodontotherium* with that of the next genus. The small *N. ovinus* was about the size of a Sheep; but its limb-bones

are unknown. In *Toxodon*, of which the type species is of large size and is found in the Pleistocene of Argentina, the dental formula is $I.\frac{2}{3}$, $C.\frac{0}{1}$, $Pm.\frac{4}{3}$, $M.\frac{3}{3}$. All the teeth (fig. 1251) grow from persistent pulps; the lower canines are very minute, the incisors large, and the crowns of both the latter and of the cheek-teeth strongly curved. The structure of the latter is a simplification of the plan obtaining in *Nesodon*. The femur has no third trochanter, the fibula articulates with the calcaneum, and the cranium approximates in some respects to that of the *Suidæ*. In the typical *T. platensis* the outermost upper incisor is the larger of the two, the



Fig. 1251.—Oral surfaces of the right upper (A) and lower (B) dentition of *Toxodon Burmeisteri*; from the Pleistocene of the Argentine Republic. Much reduced. *c*, The lower canine.

reverse condition obtaining in *T. Burmeisteri* (fig. 1251). From the infra-Pampean deposits Dr Ameghino has recently described various remains of allied forms under the names of *Toxodontotherium*, *Haplodontotherium*, and *Dilobodon*. A mandible from the Tertiary of Monte Hermosa, in Argentina, is characterised by the triangular form of the third incisor, and has accordingly been named *Trigodon* by Dr Ameghino. Dr Moreno states, however, that this mandible belongs to the same animal as the teeth described as *Toxodontotherium* and *Haplodontotherium*; and he would adopt for their owner the name *Trigodon* as the one which was alone well defined.[1] The type mandible is peculiar in having only a single median incisor, placed on the line of symphysis, but this is probably an individual abnormality. Apparently more nearly allied to *Nesodon* (which Dr Ameghino makes the type of a distinct family) are *Colpodon* and *Protoxodon*; while other allied remains described by the same writer from the Tertiaries of Argentina under the names of *Interatherium*, *Toxodontophanes*, and *Tembotherium*, are referred to two distinct families.

Family Typotheriidæ.—Perhaps still more remarkable is *Typo-*

[1] This name is really preoccupied by the earlier *Trigonodon* and *Trigonodus*.

therium (*Mesotherium*) from the infra-Pampean beds of Argentina, in which the dentition is *I.* $\frac{1}{2}$, *C.* $\frac{0}{0}$, *Pm.* $\frac{2}{1}$, *M.* $\frac{3}{3}$. The incisors grow from persistent pulps; and the structure of the cheek-teeth recalls that of *Toxodon*. The skull (fig. 1252) is of an Ungulate type; there is a third trochanter to the femur; and clavicles

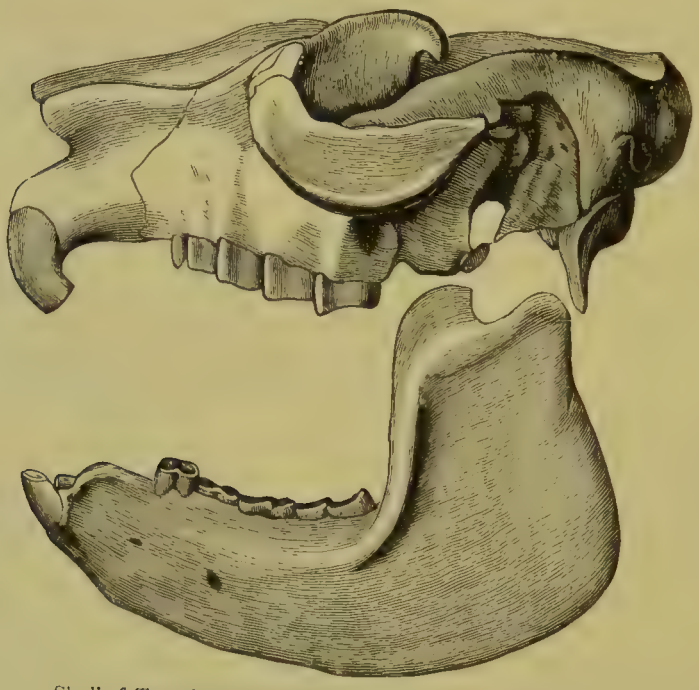


Fig. 1252.—Skull of *Typotherium cristatum*: from the infra-Pampean of Argentina. One-half natural size.

(which are unknown in any other Ungulate) are present. This peculiar genus presents characters connecting the *Toxodontidæ* with the Rodents. Allied forms from the infra-Pampean deposits of the same region have been described as *Protypotherium*, *Stenotephanus*, and *Tomodus*; while *Pachyrucus* from the later Tertiary of Monte Hermosa is a much smaller form with three premolars.

Suborder 4. Condylarthra.—This group comprises a number of very generalised Ungulates mostly from the Eocene of North America, which are grouped by Professor Cope, on account of the structure of their feet, with the Hyracoidea in a division termed Taxeopoda.[1] Both the present group and the Hyracoidea are characterised by the scaphoid of the carpus being supported by the trapezoid and not by the magnum, which carries the lunar; while in the tarsus the cuboid articulates proximally with the calcaneum

[1] Professor Cope would also include the Primates among the Taxeopoda.

only. There is but slight mutual interlocking of the carpal and tarsal bones; the structure of these joints being simpler than in the other suborders, and resembling those of the Unguiculate orders. In the Condylarthra the dental formula is nearly always the typical one; the cheek-teeth are brachydont, and usually bunodont, although rarely lophodont. The premolars are simpler than the true molars, which may be tritubercular like those of many Carnivora; the canines and incisors frequently also recall those of that order. The humerus is peculiar among Ungulates in having an entepicondylar foramen; the femur has a third trochanter; the astragalus, as in the Carnivora, presents a uniformly convex distal articular surface; and there is no articular facet for the fibula either on this bone or on the calcaneum. The feet usually have five digits, with sharply pointed terminal phalangeals; and the radius and ulna are distinct. This suborder may be regarded as containing the ancestral types from which the Artiodactyla and Perissodactyla have sprung. It further presents such remarkable signs of affinity (especially in the structure of the teeth, the form of the astragalus, and the presence of the foramen in the humerus) with the Carnivora, that it seems highly probable that we may look upon the Condylarthra as a side branch from the original ancestral stock of the Carnivora, which is most nearly represented by the more primitive Creodonts.

Family Periptychidæ.—In this the most generalised family the dentition is bunodont; the digits are five on each foot; the astra-



Fig. 1253.—*Periptychus rhabdodon.* Right upper (*a*) and lower (*b*) cheek-dentition, grinding surface; from the Puerco Eocene of New Mexico. Two-thirds natural size. (After Cope.)

galus has no trochlea; and the premolars are very simple. In the type genus *Periptychus*, from the Lowest, or Puerco, Eocene of New Mexico, the dental formula is $I.\ \frac{(2-3)}{3}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{4}{4}$, $M.\ \frac{3}{3}$, and the incisors and lower canines are small. The typical *P. rhabdodon*

(fig. 1253) is characterised by its vertically grooved premolars. Other genera from the North American Eocene are *Hexodon*, *Ectoconus*, *Anisonchus*, *Hemithlæus*, *Haploconus*, and *Zetodon*; of which the fourth may be not separable from the third. From this family Dr Schlosser regards the bunodont Artiodactyla as derived, and thinks a direct relationship can be traced from *Periptychus* to *Achænodon*, and thus to the other *Chæropotamidæ*. The humerus is short, and much expanded distally.

Family Phenacodontidæ.—In this family the brain (fig. 1254) is characterised by the extremely small size of the hemispheres,

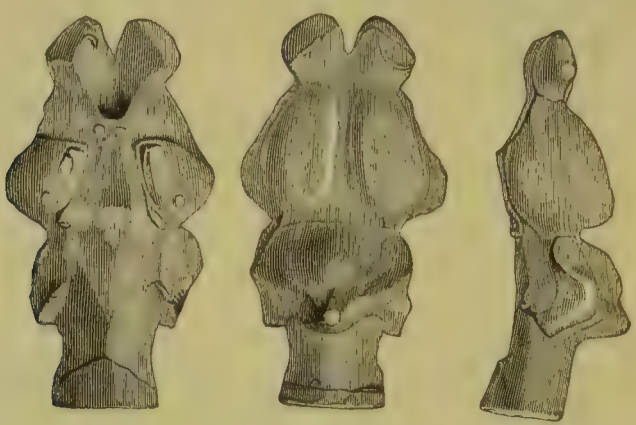


Fig. 1254.—Inferior, superior, and left lateral aspects of the brain of *Phenacodus primævus*; from the Lower Eocene of North America. (After Cope.)

which are only one-fourth longer than the cerebellum, and thus indicate a very low type of organisation. The family is readily distinguished from the preceding by having a proximal trochlea to the astragalus, by the longer neck, and less simple premolars, which are, however, different from those of the following family. The type genus *Phenacodus* (fig. 1255) includes several species from the Puerco and Wasatch Eocene of North America, varying from the size of a small terrier to that of a leopard. The dental series comprises the full typical number; and although the crowns of the upper true molars are of a bunodont structure, yet they could be readily modified into the lophodont type of *Hyracotherium*, and we must probably regard the latter as a direct descendant of the present genus, with perhaps the intervention of *Systemodon*. Professor Rütimeyer has described some upper molars from the Upper Eocene of Switzerland which he refers to *Phenacodus*, although they are much more of a lophodont type than in the American species.

Professor Cope remarks of one of the species of *Phenacodus* that "the size of the animal is about that of a Bull-dog, but the head is smaller,

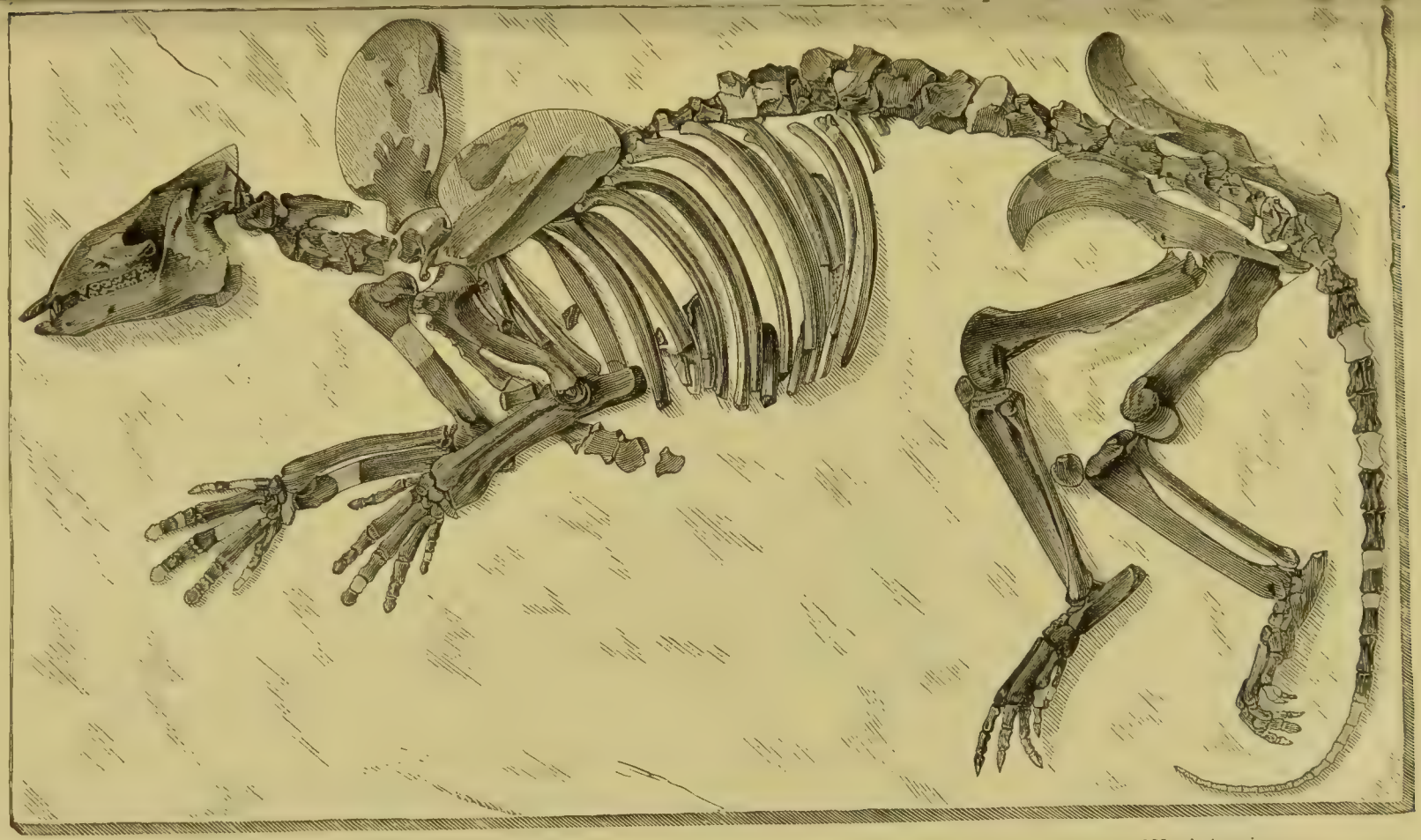


Fig. 1255.- Slab of rock showing the left lateral aspect of the skeleton of *Phenacodus primævus*; from the Lower Eocene of North America. One-seventh natural size. (After Cope.)

and the neck rather shorter and not nearly so robust. The limbs have about the same proportions to the body as those of a Bull-dog, but the anterior ones are shorter. The proportions of the parts of the limbs, and of the fore and hind limbs to each other, excepting the feet, are much as in the Collared Peccary. . . . We can thus imagine the *Phenacodus Vortmani* as an animal of the comparatively slender build of the Bull-dog, with a head and neck proportioned more as in the Racoon, and with the rump more elevated than the withers, as in the Peccary. The feet resembled those of a Tapir or Rhinoceros, but had an [additional] pair of short toes on each foot, which did not reach the ground. To this add a tail much like a Cat's in proportions, and the picture is complete. In diet the animal was omnivorous, the proportions of animal food being smaller than the Hogs, for instance, use. The food is more likely to have resembled that of the Primates. What means of defence this species had is not easily surmised, as the canine teeth and hoofs are not large."

The species represented in the accompanying woodcut was of larger dimensions; Professor Cope stating that it was intermediate in size between a Sheep and a Tapir. Comparing it to an animal with an equally long tail, we might perhaps take a Leopard as a fair representative. The remarkable length of the tail at once shows a wide difference from all existing Ungulates. Professor Cope, from the structure of the bones of the nasal region, suggests that the head may have had a short proboscis.

Other genera from the American Eocene are *Protogonia*, *Anacodon*, and *Diacodexis*. The former occurs in the Puerco, and typically has but one outer tubercle to the fourth premolar, in place of the two of *Phenacodus*. Professor Rütimeyer refers to this genus teeth from the Upper Eocene of Switzerland.

Family Meniscotheriidæ.—This family is taken to include two genera characterised by their lophodont dentition, which are evidently more specialised than the preceding types. By Dr Schlosser they are regarded as allied to the *Chalicotheriidæ*, and there are perhaps indications of affinity between the European genus and the Hyracoidea. The humerus is longer and less expanded than in the *Periptychidæ*, but the number of the digits is unknown. There is no marked diastema in the dental series. The typical genus *Meniscotherium* is from the Wasatch Eocene of New Mexico, and is characterised by its small incisors, and the presence of two outer lobes to the last upper premolar. Teeth from the Swiss Eocene have been referred to this genus. In *Hyracodontotherium*, from the Upper Eocene of France, the upper incisors are large and curved, the first being especially enlarged, and closely resembling the corresponding tooth of *Hyrax;* the canine is small, and resembles the third incisor; while the fourth premolar has but a single outer lobe or tubercle. Two species are known by the skull.

Suborder 5. Hyracoidea.—As mentioned under the head of the Condylarthra, the structure of the carpus and tarsus in the Hyracoidea is the same as in that suborder, but the terminal phalangeals are truncated, and there is an interlocking articulation be-

tween the fibula and astragalus. This suborder is represented solely by the family *Hyracidæ*, containing the two existing genera *Hyrax* (fig. 1256) and *Dendrohyrax;* both of which are confined to Africa and Syria, and are unknown in a fossil condition. The dental formula of the adult is $I.\ \frac{1}{1}$, $C.\ \frac{0}{0}$, $Pm.\ \frac{4}{4}$, $M.\ \frac{3}{3}$; there are four milk-molars; the incisors grow from persistent pulps, and the pattern of the cheek-teeth is of a Rhinocerotic type. The fore-feet have

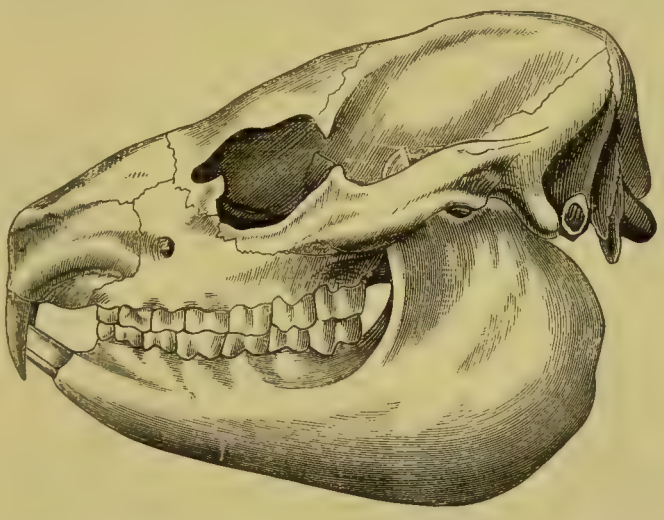


Fig. 1256.—Left lateral aspect of the skull of *Hyrax capensis*. Reduced.

three, and the hind ones four digits; and the terminal phalangeals (except in the inner digit of the pes) have rounded hoof-like nails. The coracoid process of the scapula is well developed; there is no entepicondylar foramen to the humerus; the femur possesses a small third trochanter; and the tibia and fibula are distinct.

Suborder 6. Amblypoda.—In this suborder, which comprises primitive Ungulates of great bulk from the Eocene of Europe and North America, the carpus (fig. 1257, B) is characterised by the scaphoid being supported by the trapezoid and not by the magnum, while the latter and the unciform support the lunar; in the tarsus the cuboid articulates with both the calcaneum and astragalus. The carpus is therefore of a more primitive type than the tarsus. Both the carpal and the tarsal bones interlock to a slight extent (fig. 1257, B, C); the astragalus is flat (fig. 1257, C); the feet are short, plantigrade, and furnished with five digits; and the fibula articulates with the calcaneum. The brain (fig. 1257, A) is very small in proportion to the cranium. The cheek-dentition (fig. 1258) is of a primitive lophodont type; the crowns of all these teeth being very short,

and the upper true molars and the hinder premolars bearing two main oblique ridges, which usually form one or two V's. Upper and lower canines are always present. The pelvis (as seen in fig. 1260) resembles that of the Elephants in the enormous expansion and vertical position of the ilia, but is distinguished by the circumstances that the ischia do not enter into the ventral symphysis. This suborder is usually divided into three sections; but a form

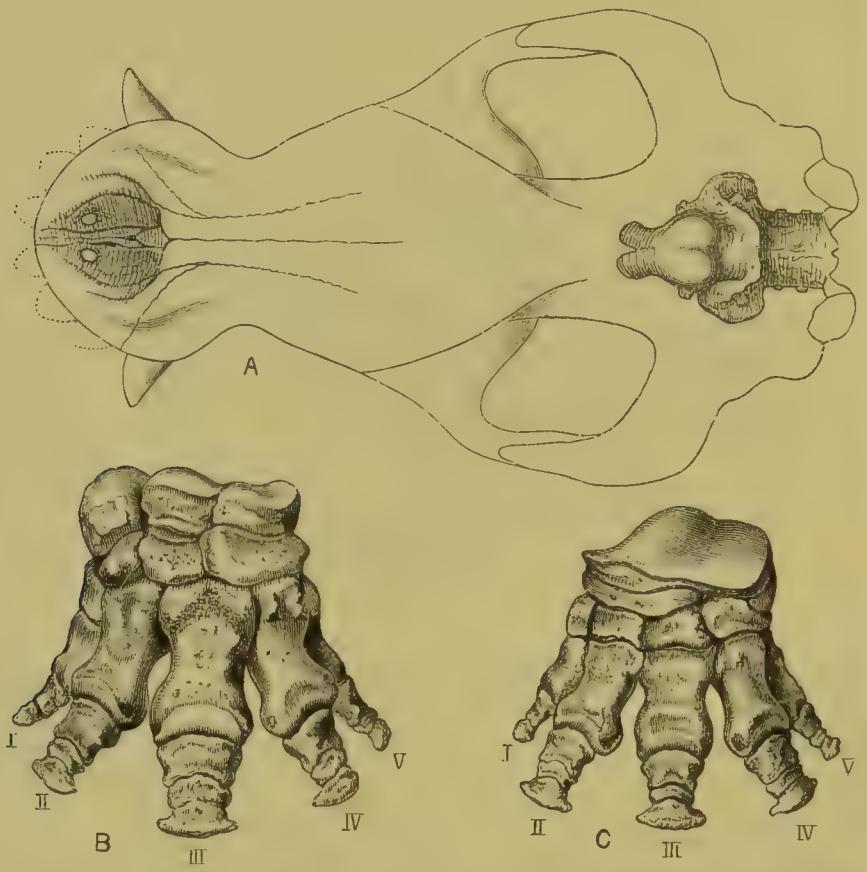


Fig. 1257.—Outline of upper aspect of cranium (A), the left manus (B[1]) and pes (C) of *Coryphodon hamatus;* from the Wasatch Eocene of North America. A, one-fifth, B and C, one-third natural size.

recently discovered in the Bridger Eocene of North America, and named *Elachoceros*, presents characters connecting the last two, and will perhaps render it eventually necessary that they should be abolished. Excluding this form, the characters of the three sections are as follows:—

[1] In the first row of carpal bones the one on the right of the figure is the cuneiform, the central one the lunar, and that on the left the scaphoid; in the second or lowest row the bone on the right is the unciform, the central one the magnum, and the one on the left the trapezoid.

Section A. Taligrada.—The astragalus has a head; there is a third trochanter to the femur; and superior incisors are present.

Family Pantolambdidæ.—The one family of this section is represented by the genus *Pantolambda*, from the Puerco, or Lowest, Eocene of New Mexico, which presents the feature, quite unique



Fig. 1258.—Left upper cheek-dentition of *Coryphodon hamatus;* from the Wasatch Eocene of North America. One-half natural size. (After Marsh.)

among lophodont Ungulates, of having the upper true molars with narrow subtriangular crowns like those of the premolars of *Coryphodon* (fig. 1258). This is a very important feature, as showing the relationship of the dentition of the Ungulata to that of the Carnivora; and also as indicating that those Ungulates which have the upper premolars as complex as the true molars, are more specialised than those in which the reverse condition obtains.

Section B. Coryphodontia.—In this group, which Professor Cope terms Pantodonta, the astragalus has no head; there is a

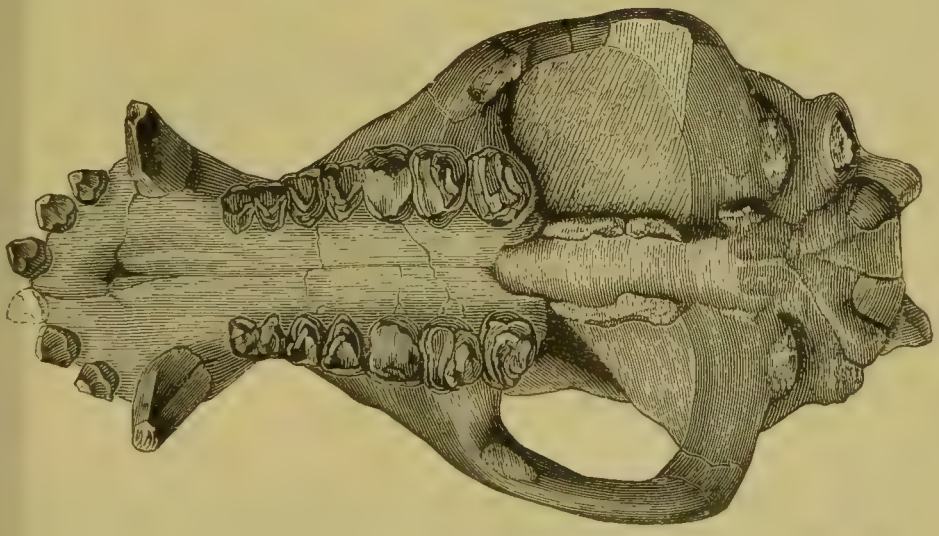


Fig. 1259.—Palatal aspect of the cranium of *Coryphodon hamatus;* from the Wasatch Eocene of New Mexico. Two-ninths natural size. (After Cope.)

third trochanter to the femur; and upper incisors are present. The cranium has no protuberances, and the development of the upper canines is not excessive.

Family Coryphodontidæ.—The upper premolars (fig. 1258) are simpler than the true molars, and there are frequently two V-shaped ridges on the latter. The type genus *Coryphodon* was originally founded by Sir R. Owen upon a lower molar from the London Clay; other teeth were subsequently found in the Lower Eocene of

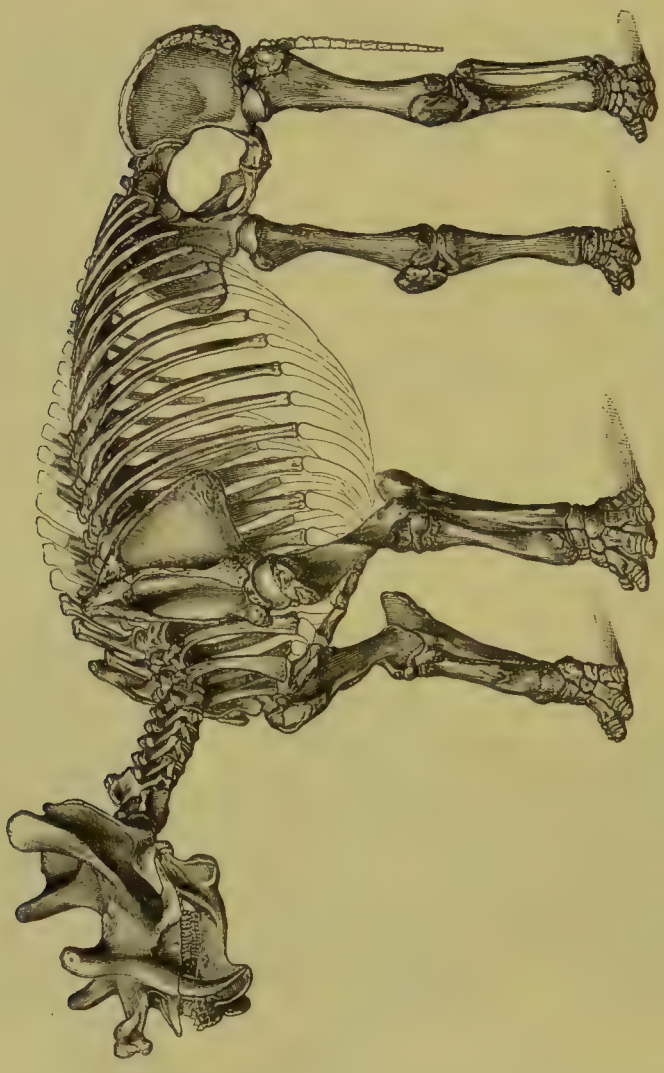


Fig. 1260.—Restoration of the skeleton of *Uintatherium ingens*; from the Bridger Eocene of Wyoming, United States. One-thirtieth natural size. (After Marsh.)

the Continent, but it was reserved for the discoveries in the homologous strata of North America to indicate the full structure of this curious genus. The dentition is *I.* $\frac{3}{3}$, *C.* $\frac{1}{1}$, *Pm.* $\frac{4}{4}$, *M.* $\frac{3}{3}$; and the structure of the upper molars, cranium, and feet is exhibited in the three accompanying woodcuts (figs. 1257-1259.) Other forms from the Eocene of America have received the names of *Metalophodon*

Bathmodon, *Ectacodon*, and *Manteodon;* but further observations are required to show whether all of these are really distinct from the type genus.

Section C. Dinocerata.—The third section of this suborder, which Professor Marsh regards as entitled to rank as a distinct suborder, is represented by the now well-known Dinocerata, which are exclusively confined to the Upper or Bridger Eocene of North America. These animals were ponderous brutes, nearly as bulky as an Elephant, to which group they present many curious points of resemblance. The skull (figs. 1261-1263) bears several large protuberances; and the upper canines of the males were enormously developed (recalling those of the Feline genus *Machærodus*), and were frequently protected from injury by a descending flange developed from the symphysis of the mandible, as is well shown in the figure of the skeleton. A peculiar and characteristic feature is the total absence of upper incisors; while another distinctive character is the want of a third trochanter to the femur, which thus resembles the corresponding bone of the Proboscidea.

Family Uintatheriidæ.—The whole of the members of the

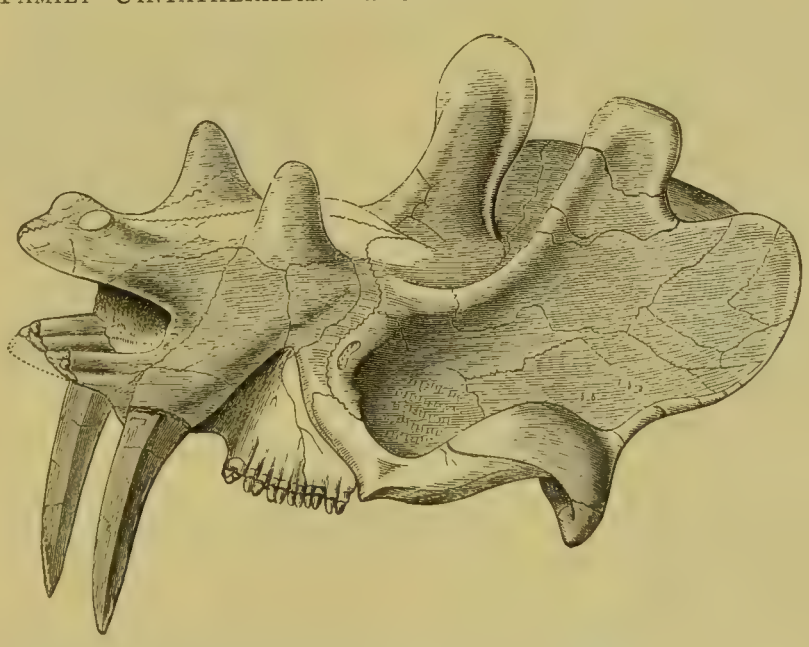


Fig. 1261.—Left lateral view of the skull of *Uintatherium mirabile;* from the Bridger Eocene of Wyoming. Much reduced. (After Marsh.)

section may be included in this family—the equivalent of the *Tinoceratidæ* of Professor Marsh. The hinder upper premolars are as complex as the true molars, and there is no distinct third lobe to the last lower true molar; while in the hinder cheek-teeth of the

upper jaw the two transverse ridges unite on the inner border of the crown to form a V; another V, with its angle directed inwardly, occurring in the corresponding lower teeth. The least specialised genus is *Bathyopsis*, of the lower part of the Bridger Eocene, in which the lower canine is separated from the incisors, and bites in front of the upper canine in the normal manner; thus connecting the more specialised forms with *Coryphodon*. Another form of comparatively small size, distinguished by the absence of nasal prominences, is apparently also entitled to generic distinction, and has been named *Elachoceros*. The typical forms, according to

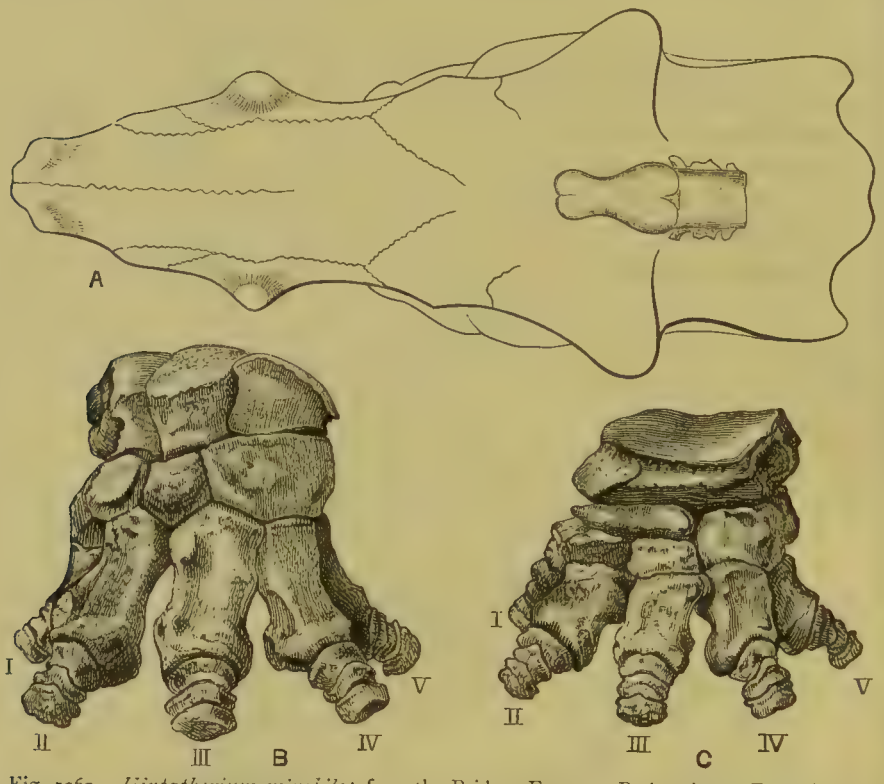


Fig. 1262.—*Uintatherium mirabile;* from the Bridger Eocene. Reduced. A, Frontal aspect of cranium; B, Left manus; C, Left pes. In B the middle bone of the top row is the lunar, while the oval bone on the left of the second row is the trapezoid. The topmost bone in C is the astragalus. (After Marsh.)

Messrs Scott and Osborn, may all be grouped under the generic name of *Uintatherium*, although they have been split up by many writers into several genera under the names of *Dinoceras*, *Octotomus*, *Tinoceras*, *Eobasileus*, and *Loxolophodon*. This genus may be characterised by the presence of nasal tuberosities (fig. 1261), and by the lower canine being approximated to the incisors, which it resembles in structure. The dental formula is usually $I.\frac{0}{3}$, $C.\frac{1}{1}$,

Pm. $\frac{3}{3}$, *M.* $\frac{3}{3}$; but according to Professor Cope the lower incisors may be wanting. The genus may be divided into a *Dinoceratine* and a *Tinoceratine* group. The former, which includes *Dinoceras* of Marsh and *Octotomus* of Cope, comprises the smaller forms from the typical Bridger, in which the nasals are not greatly produced, and their prominences are comparatively small (figs. 1261, 1262). According to Professor Marsh, the base of the upper canine is vertical, and the lunar has a small facet for articulation with the trapezoid (fig. 1262, B); the neck being comparatively short. In the second group, comprising *Tinoceras* of Marsh, and *Eobasileus* and *Loxolophodon* of Cope, all the species are of huge size, and have the nasals overhanging the premaxillæ, with the prominences very large (figs. 1260, 1262). These species are confined to the upper Bridger, and have the base of the upper canine horizontal, the trapezoid not articulating with the lunar, and the neck longer. The species, of which the skull is shown in fig. 1262, is remarkable for having the

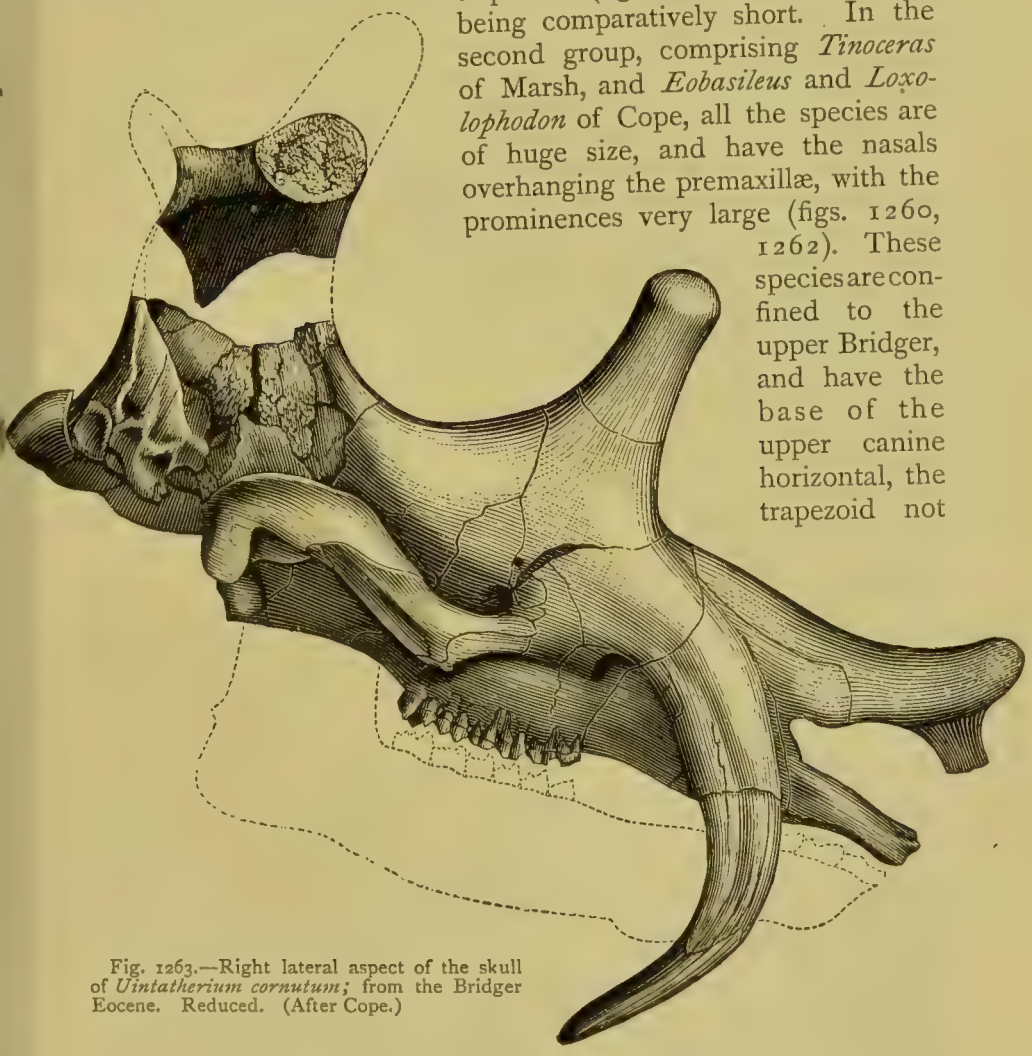


Fig. 1263.—Right lateral aspect of the skull of *Uintatherium cornutum;* from the Bridger Eocene. Reduced. (After Cope.)

second pair of prominences placed over the orbit, instead of much further back, as in fig. 1260.

Writing of the Dinocerata Professor Marsh observes that "the fossil remains of this group have hitherto been found in a single Eocene lake-basin of Wyoming, and none are known from any other part of this country or from the Old World. These gigantic beasts, which nearly equalled the Elephant in size, roamed in great numbers about the borders of the ancient tropical lake, in which many of them were entombed. This lake-basin, now drained by the Green River, the main tributary of the Colorado, slowly filled up with sediment, but remained a lake so long that the deposits formed in it, during Eocene time, reached a vertical thickness of more than a mile. . . . At the present time this ancient lake-basin, now 6000 to 8000 feet above the sea, shows evidence of a vast erosion, and probably more than one-half of the deposits once left in it have been washed away, mainly by the action of the Colorado river. What remains forms one of the most picturesque regions in the whole West, veritable *mauvaises terres*, or bad lands, where slow denudation has carved out cliffs, peaks, and columns of the most fantastic shapes and colours. This same action has brought to light the remains of many extinct animals, and the bones of the Dinocerata, from their great size, naturally first attract the attention of the explorer." The latter part of this description recalls to mind the very similar conditions of the Pliocene Siwalik deposits of Northern India, where the place of the bones of Dinocerata is taken by that of Proboscidea. The Professor proceeds to mention that the first remains of these wonderful animals were obtained by him in the year 1870.

In respect to their structure the same writer observes that in the cranium "each maxillary bone carried a well-developed process, probably of the nature of a horn-core. The nasals support two similar but smaller horn-cores; and the frontals are developed behind into two larger bony projections, most probably also of the nature of horn-cores. The animal thus possessed three pairs of horn-cores, one carried by the upper jaw-bones, one by the nasals, and one by the frontal bones. Whether, however, these so-called 'horn-cores' really supported horns, of the nature of the horns of the Cavicorn Ruminants, is quite a matter of conjecture; and there is much probability in the view entertained by Owen—namely, that some of them were simply covered by callous integument."

As regards the mental powers, Professor Marsh remarks: "The brain-cavity of *Uintatherium* is perhaps the most remarkable feature in this remarkable genus. It proves conclusively that the brain (fig. 1262, A) was proportionately smaller than in any other known mammal, recent or fossil, and even less than in some reptiles. It is, in fact, the most reptilian brain in any known mammal. In *U. mirabile* the entire brain was actually so diminutive that it could apparently have been drawn through the neural canal of all the presacral vertebræ, and certainly through the cervicals and lumbars."

Suborder 7. Proboscidea. — The last of the suborders into which the Ungulates are divided is that of the Proboscidea, represented at the present day solely by the two species of Elephant, but in past epochs including a large number of more or less closely allied forms. These animals are of huge bulk and stout build, and

include the largest known mammals. They present the following characteristic features; those of the soft parts being, of course, only known in the existing species. The nose is produced into a long flexible proboscis terminated by the nostrils (fig. 1264); from which feature the name of the suborder is derived. The limbs are stout, with their segments placed nearly in a vertical line (fig. 1267), and the proximal segment the longer. In the second segment the two component bones (radius and ulna in the fore, and tibia and fibula



Fig. 1264.—Skull of the Indian Elephant (*Elephas indicus*). Greatly reduced. *i*, Tusk-like upper incisors; *m*, Lower jaw; *n*, Nostrils, placed at the end of the proboscis.

in the hind limb) are distinct. In the carpus the scaphoid is supported by the trapezoid, but not by the magnum, the latter supporting the lunar; while in the tarsus the cuboid articulates proximally with the distal face of the navicular, but not with the astragalus. In both the carpus and tarsus the component bones interlock but very slightly; the type of structure of the tarsus being one step in advance of that obtaining in the Condylarthra. The feet (fig. 1265) are plantigrade; there are five digits to each foot; the astragalus (fig. 1265) is flat; the femur has no third trochanter; the fibula articulates with the calcaneum; and the jugal forms the middle of the zygomatic arch. The brain is of large size; canines appear to be always absent; while incisors, growing from persist-

ent pulps, are present either in the upper or lower jaws of the males of all the forms at present known. The cheek-teeth may attain extreme complexity; and the true molars always consist of transverse ridges, which may vary greatly in height, and may be either uninterrupted, or split up into inner and outer columns, which may have a more or less alternate arrangement; there are never fewer than three such ridges in the last milk and the first true molars; and the intervening valleys may be either entirely open, or blocked by accessory tubercles, or completely filled with cement. The toes are all invested in a common integument, although furnished with distinct broad hoofs; and the third digit of each foot is the largest. There are two anterior venæ cavæ entering the right auricle of the heart; the stomach is simple; there is a large cæcum; the testes are permanently retained in the abdomen; the uterus has two cornua; and the placenta is non-deciduate and zonary.

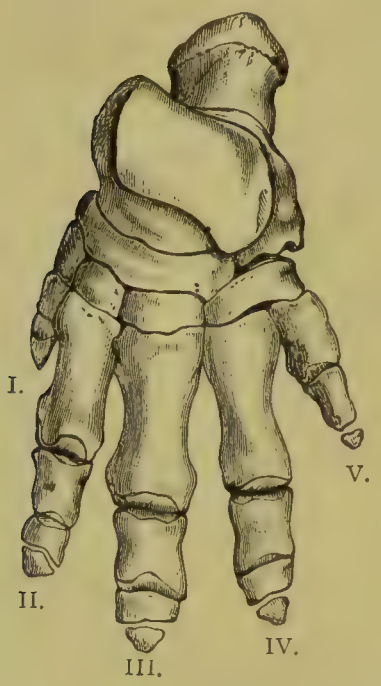


Fig. 1265.—Dorsal aspect of the left pes of the Indian Elephant (*Elephas indicus*). Greatly reduced. (After Cuvier.) The numbers indicate the digits. The uppermost bone is the calcaneum, resting upon which is the astragalus, with its flat tibial surface. The bone with a long narrow dorsal surface immediately below the astragalus is the navicular; while the one supporting the metatarsals of the fourth and fifth digits is the cuboid.

In the skull and dentition the members of this suborder are decidedly specialised; but in other respects, such as the structure of the limbs, and the presence of two venæ cavæ, they show very generalised features; and there are not wanting indications of a remote affinity with the Rodents, and perhaps the Sirenia. It will be shown as we proceed that the structure of the cheek-dentition has advanced from a comparatively generalised type in *Dinotherium* to an extremely specialised one in the existing species of Elephants; and it appears that this specialisation "has followed to a considerable extent a line analogous to that obtaining in the Perissodactyla and Artiodactyla, and shows itself in the increased height and complexity of the crowns of these teeth and in the final attainment of a nearly horizontal and continuous plane of wear. From the structure of the cheek-teeth in the more generalised members of the suborder, it may be inferred that the action of the molars of one jaw upon those of the other must have been mainly a scissor-like or snapping

one, while in the more specialised forms this action has been converted into a perfect grinding motion."[1]

The pelvis of the Proboscidea is characterised by the vertical position and great expansion of the large ilia, and the very small size of the ischia and pubes, both of which enter into the formation of the very short symphysis.

The Proboscidea make their first appearance in the Middle Miocene (Sansan stage) of Europe; but we are still unacquainted with any form which connects them decidedly with the other suborders of the Ungulata, although *Dinotherium* affords an inkling of how such a transition may have taken place. The Mastodons probably originated in Europe, from whence they travelled to India, and there gave origin to the peculiar Stegodont group of Elephants, which are the parents of the existing specialised forms. From the eastern regions of the Old World it seems probable that the higher Elephants travelled back to Europe, while they also reached North America in the Pleistocene epoch; Mastodons having arrived in the New World during the preceding Pliocene period.

Family Dinotheriidæ.—This family is at present known solely by the genus *Dinotherium*, of which the remains are found in the

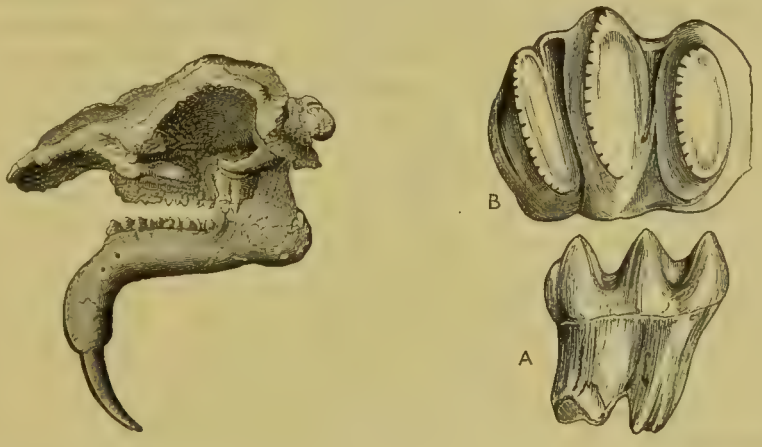


Fig. 1266.—Skull, and lateral (A) and oral (B) aspects of the first lower true molar of *Dinotherium giganteum*; from the Upper Tertiary of Europe. All the figures are reduced; the reduction of B being less than that of A.

Miocene and Pliocene of Europe and India. The type species is *D. giganteum* (fig. 1266), originally described by Cuvier, upon the evidence of a molar tooth from the Middle Miocene of the Orleannais, as a gigantic Tapir, but better known by the cranium and

[1] Quoted from the writer's 'Catalogue of Fossil Mammalia in the British Museum,' pt. iv., from which other extracts have already been made.

jaws obtained by Drs Kaup and Klipstein from the Lower Pliocene of Eppelsheim, in Hessen-Darmstadt. *Dinotherium* was an animal of the bulk of an Elephant, characterised by the presence of a pair of tusk-like, backwardly-curved incisors in the lower jaw, and by having in the adult five cheek-teeth, of which the two first are premolars. The true molars carry simple, low, transverse ridges; of which there are three in the first tooth of the series (fig. 1266, A, B), and two in each of the others. The upper premolars differ from the true molars in having their two transverse ridges connected on the outer side by a longitudinal ridge, which causes these teeth to be of the lophodont type of those of the Tapirs. In the young animal there were three milk-molars in each jaw, which resemble the true molars in structure; each of the first two having a pair of transverse ridges, while the third has three of these ridges, and thus resembles the first true molar. The number of ridges in the milk and true molars may therefore be represented by the ciphers *Mm.* $\frac{2 \cdot 2 \cdot 3}{2 \cdot 2 \cdot 3}$, *M.* $\frac{3 \cdot 2 \cdot 2}{3 \cdot 2 \cdot 2}$; the import of which we shall notice under the head of the *Elephantidæ*. *Dinotherium indicum*, from the Upper Miocene and the Lower Pliocene of North-western India, was probably nearly allied to the European species.

Family Elephantidæ.—With this family we enter a group of animals in which the succession of the cheek-teeth presents such marked peculiarities as to require special notice at the outset. In the existing members there are normally six of such teeth, which increase gradually in size and complexity from the first to the last. The last three of these teeth correspond to the true molars of less aberrant Ungulates, while the anterior ones represent the last three milk-molars of the same. These milk-teeth are not succeeded by premolars, but the whole series of teeth is gradually pushed forwards in the jaw; the anterior teeth being worn away and their roots absorbed before the hinder ones come into use. In consequence of this arrangement, and the large absolute size of the teeth, there are never more than portions of two cheek-teeth on either side of each jaw in use at any one time, as is shown in fig. 1264. The cheek-teeth of the existing Elephants will therefore correspond to *Mm.* 2 + *Mm.* 3 + *Mm.* 4 + *M.* 1 + *M.* 2 + *M.* 3 of the typical series, but it is not improbable that in very rare instances *Mm.* 1 may also be developed. If we had to depend entirely on the evidence of the existing forms, there might be some doubt as to the serial homology of the three teeth which we reckon as milk-molars; but this question is set at rest by some of the fossil forms, in which these teeth were vertically succeeded by small, and usually functionless, premolars. The total disappearance of the premolars, and the persistence of the milk-molars in the higher forms, is the widest departure from

the simple marsupial dentition known in the whole class. In some of those fossil forms in which the structure of the cheek-teeth is simpler, there may be portions of three such teeth in use at the same time. The serial position of individual teeth in any one species can be more or less exactly determined by their absolute size, and the number of transverse ridges which they carry. In all members of the family there are never less than three ridges in the fourth milk-molar and the first and second true molars (which are often collectively spoken of as the "intermediate molars"), while the last true molar has one or more ridges in excess of the preceding tooth. Incisors are always present in the upper jaw of male individuals, and may or may not be also developed in the lower jaw. In transverse section the dentine of these teeth displays a peculiar arrangement of decussating lines, similar to the "engine-turning" on the back of a watch-case, by the presence of which true ivory can always be recognised.

The earliest and least specialised genus of this family is *Mastodon*,[1] in which premolars and lower incisors are frequently present, and

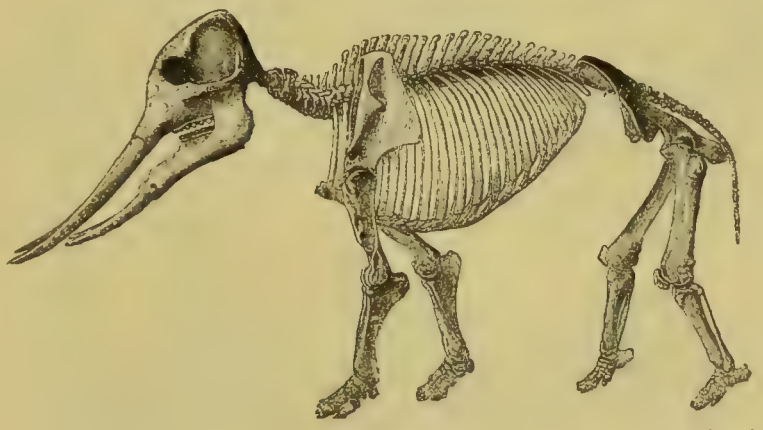


Fig. 1267.—Restoration of the skeleton of *Mastodon angustidens*. Greatly reduced. (After Gaudry.)

the upper incisors may have longitudinal bands of enamel. The cheek-teeth carry transverse ridges, which may be entire or may be divided into distinct inner and outer columns with a more or less

[1] Professor Cope proposes an arrangement of the *Elephantidæ* differing from the one generally adopted. Thus the genus *Mastodon* is split up into *Tetrabelodon*, in which there are both upper and lower tusks, and the former have an enamel-band; *Dibelodon*, in which the lower tusks are usually wanting, but the upper ones have an enamel-band; and *Mastodon*, in which there are no lower tusks, and no enamel-band on the upper ones. *Elephas* is divided into *Emmenodon*, typically represented by *Elephas Clifti* (apparently the type of *Stegodon*), but also including *E. planifrons*, and characterised by the presence of premolars; and *Elephas*, which is taken to include all the other species.

alternate arrangement; outlying tubercles may be present in the intervening valleys, which are frequently entirely devoid of cement, and are never completely filled by it. All the "intermediate" molars usually have the same number of ridges; this number varying from three to five. The ridges are always bisected by a median cleft traversing the long axis of the crown; and the plane of wear of the crowns of the teeth is oblique, that of the upper jaw inclining from



Fig. 1268.—*Mastodon angustidens.* The fourth left lower milk-molar; from the Lower Siwaliks of India.

the outer to the inner side, and the reverse obtaining in the lower. Three cheek-teeth may be in use at the same time, and the symphysis of the mandible may be greatly elongated. The vertex of the cranium (fig. 1267) is usually but slightly elevated, as in the majority of Ungulates; and in the less specialised forms (as may be seen by comparing fig. 1267 with fig. 1270) the proportions of the

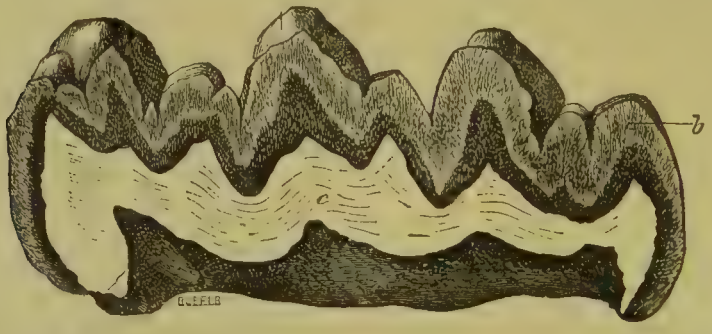


Fig. 1269.—*Mastodon angustidens.* Vertical longitudinal section of the first lower true molar; from the Middle Miocene of France. Two-thirds natural size. *b*, Enamel; *c*, Dentine. (After Gaudry.)

entire skeleton depart less widely from the same type. The genus has been divided into two groups, according to the number of ridges in the cheek-teeth. In the first or *Trilophodont* group, the number of complete ridges in each of the three "intermediate" molars is three (fig. 1268); the ridge-formula of the complete series of cheek-

teeth being represented by the ciphers *Mm.* $\frac{1 \cdot 2 \cdot 3}{1 \cdot 2 \cdot 3}$, *M.* $\frac{3 \cdot 3 \cdot 4}{3 \cdot 3 \cdot 4}$. It will be noticed that in this section the number of ridges in the third and fourth milk-molars and the first true molar is the same as in *Dinotherium*.

One of the earliest examples of this group is *M. angustidens* from the higher Miocene of both Europe and India, of which two lower cheek-teeth are represented in plan and section in figs. 1268 and 1269. The simple structure of these teeth is shown in the section, where the valleys separating the low, interrupted ridges, are seen to be devoid of cement, although partially blocked by outlying tubercles. The imperfect fourth ridge at the hinder extremity (right side of figures) of these teeth is termed the *talon*. The mandibular symphysis (fig. 1267) in this species was elongated and furnished with a pair of incisors; while the milk-molars were succeeded by premolars. Allied to this species are *M. pandionis* of the Upper Miocene and Pliocene of India, and *M. pentelici* of

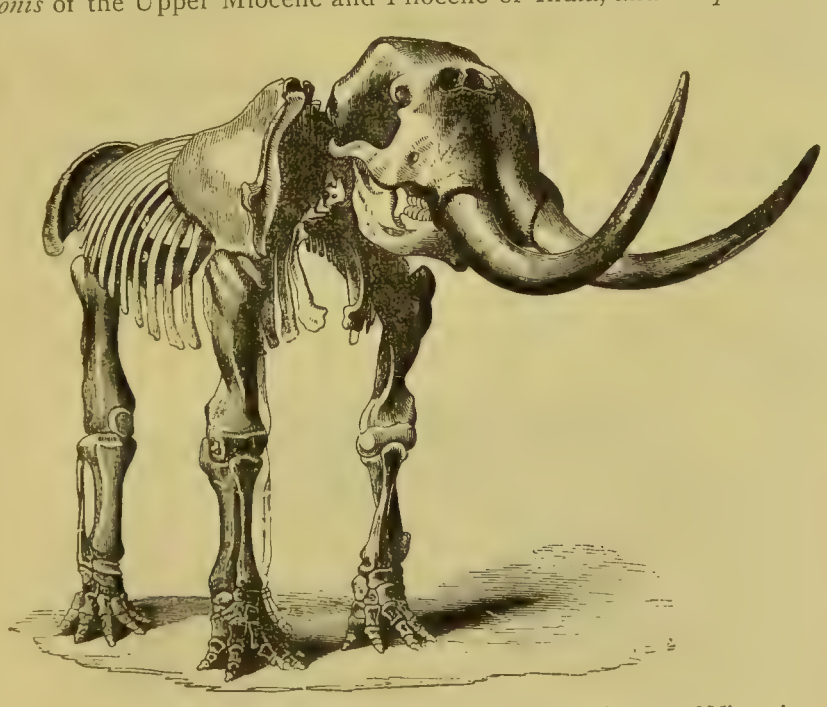


Fig. 1270.—Skeleton of *Mastodon americanus;* from the Pleistocene of Missouri. Much reduced.

the Lower Pliocene of Attica, Hungary, Samos, and Persia. From *M. angustidens* there is but a step to the contemporaneous European *M. turicensis*, in which the ridges of the molars extend straight across their crowns, without outlying tubercles in the valleys; and from this species, again, the transition is easy to the Pliocene *M. Borsoni* of Europe, in which the mandibular symphysis has become shortened in consequence of the absence of lower incisors. A later offshoot from the same branch is found in *M. americanus* (frequently known as *M. giganteus*,

or *ohioticus*) of the Pleistocene of North America. Remains of this species (figs. 1270, 1271) are exceedingly abundant in the celebrated "Big-Bone-Lick" of Kentucky, in which region the species survived into the human period. Although the mandibular symphysis is short, a single small incisor is occasionally found on one side of the jaw; premolars had however disappeared.[1] Other Trilophodont species are *M. Humboldti* and *M. cordillerum* (*andium*) of the Pleistocene of South America, in both of which the transverse ridges of the cheek-teeth are broken into columns. The former species is distinguished by the short and edentulous symphysis of the mandible. According to Dr Falconer, the latter had an elongated mandibular symphysis and large lower incisors; but Dr Burmeister states that this reference is incorrect, and that the symphysis was short and tuskless.



Fig. 1271.—Outer view of second left lower true molar of *Mastodon americanus*. Reduced.

In the *Tetralophodont* group the number of ridges in the cheek-teeth is greater than in the former group, there being usually four in the "intermediate" and five in the last true molars; but there may be occasionally five in the former and six in the latter. The complete normal ridge-formula is, therefore, *Mm.* $\frac{2-3-4}{2-3-4}$, *M.* $\frac{4-4-5}{4-4-5}$.

In this group *Mastodon arvernensis*, from the Upper Pliocene of Europe, is characterised by the number of accessory tubercles on the



Fig. 1272.—*Mastodon arvernensis*; the fourth left upper milk-molar; from the Norwich Crag. (After Lyell.)

crowns of the cheek-teeth (fig. 1272) and the somewhat alternate arrangement of the inner and outer columns of their transverse ridges, by which

[1] It appears probable that these teeth may occasionally be developed as an abnormality.

means the transverse valleys become more or less completely blocked. Closely allied to this species is *Mastodon sivalensis*, of the Pliocene of Northern India, of which a last upper true molar is represented from the lateral aspect in fig. 1273; in this species there are occasionally five

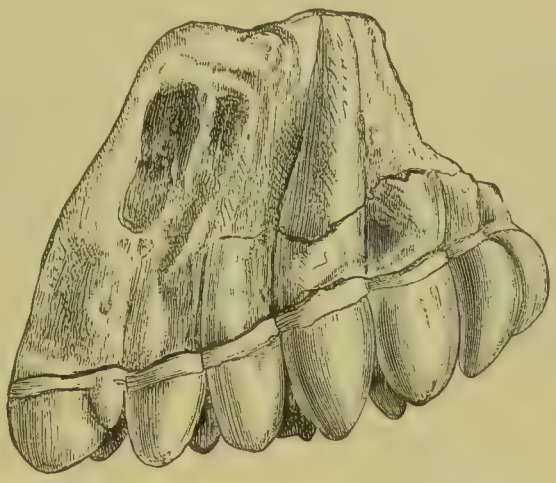


Fig. 1273.—Profile view of last upper true molar of *Mastodon sivalensis*; from the Pliocene of the Siwalik Hills of India. Reduced.

ridges in the "intermediate" molars, and the last upper true molar (as in the figure) may have six ridges and a hind talon; the blocking of the valleys by the alternate arrangement of the inner and outer columns of the ridges is well exhibited in the woodcut. Both in this species and *M. arvernensis* the symphysis of the mandible is short and tuskless, as in the modern Elephants; and the Siwalik species is further characterised by the great elevation of the vertex of the skull (fig. 1274), in which respect it also agrees with the last-named group. Both these species must be regarded as highly specialised forms which have diverged from the line connecting the *Trilophodont* group with the true Elephants. We may here briefly mention *M. perimensis* and *M. punjabiensis* of the Indian Pliocene, which show certain characters intermediate between the two above-mentioned species and *M. longirostris*, which we now proceed to notice. The last-named species occurs typically in the Lower Pliocene bone-sand of Eppelsheim in Hessen-Darmstadt, but has been also found in the English Red-Crag. It has an elongated mandibular symphysis furnished with a pair of short incisors (fig. 1275), and



Fig. 1274.—Left lateral view of the skull of *Mastodon sivalensis*; from the Siwalik Hills of India. Greatly reduced. (After Falconer and Cautley.)

the ridges of the cheek-teeth (fig. 1276) are nearly straight, and the intervening valleys only partially blocked by tubercles. The latter woodcut shows the progressive increase in the number of ridges of the milk-molars of the present group; the first and second true molars, which



Fig. 1275.—Left lateral view of the imperfect skull of *Mastodon longirostris*; from the Bone-sand of Hessen-Darmstadt. Much reduced. (After Kaup.)

would follow the fourth milk-molar (the right-hand tooth in the figure), each have the same number of ridges as the latter. *M. Cautleyi*, of the Pliocene of Western India, is a form connecting the last species with *M. latidens*. The latter is very widely distributed, ranging in the Pliocene



Fig. 1276.—The three left upper milk-molars of *Mastodon longirostris*; from the Bone-sand of Hessen-Darmstadt. (After Kaup)

from India and Burma to Borneo; the symphysis of the mandible is short; the molars (fig. 1277) are very wide, with their ridges and valleys straight and uninterrupted; and these teeth pass so completely into the type of those of the least specialised species of *Elephas* as to indicate

that there is really no distinction between that genus and *Mastodon*, although the retention of the latter term for the more generalised forms of what would be otherwise a very unwieldy genus is convenient.



Fig. 1277.—Crown surface of the third left upper true molar of *Mastodon latidens*; from the Pliocene of Borneo. Two-thirds natural size.

With the above-mentioned proviso as to its apparent passage into *Mastodon* we may note the chief features of the existing genus *Elephas*.

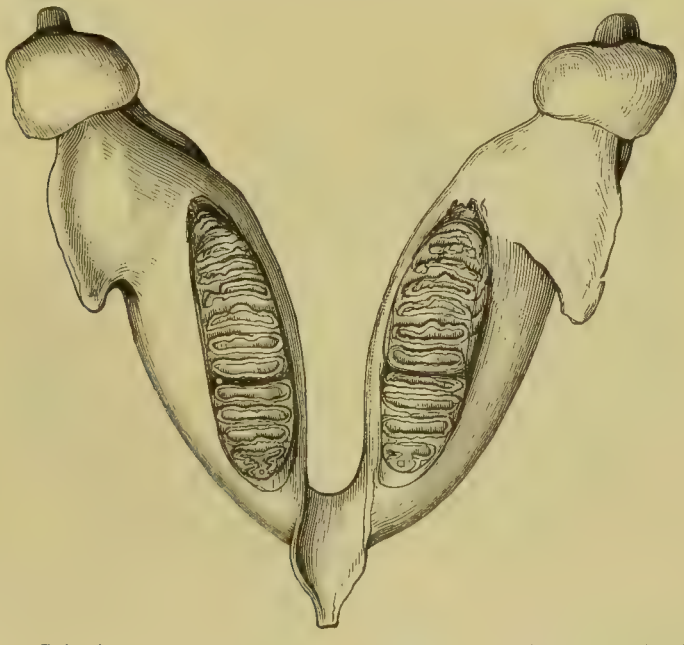


Fig. 1278.—Palatal view of the mandible of the Indian Elephant (*Elephas indicus*). Greatly reduced. The hinder portion of the penultimate and the anterior half of the last true molars are in use.

Thus lower incisors (tusks) are invariably wanting; the enamel on the upper incisors merely forms a small cap at their extremities;

premolars are nearly always absent; while the mandibular symphysis is never produced into a long rostrum, but usually terminates in a short spout-like channel, as in fig. 1278. The ridges of the true molars extend straight across their crowns, and generally show no sign of division into inner and outer columns; there is always a certain quantity of cement in the valleys between the ridges; and in those species in which these ridges become developed into tall thin plates, the cement forms equally tall laminæ filling the intervening spaces. In the least specialised forms the number of the ridges in the "intermediate" molars may be as low as five; while those in the last true molar may vary from seven in the least specialised to upwards of twenty-four in the most specialised species. Finally, it is only in a few of the more generalised species that the "intermediate" molars have an isomerous ridge-formula.

Like the Mastodons, this genus is divided into two groups, according to the structure of the teeth. In the first, or *Stegodont*, group, which is entirely confined to the Eastern parts of the Old World, the number of ridges in the cheek-teeth is comparatively low, and there may be only five or six of such ridges in the "intermediate," and from seven to eleven in the last upper true molars.

The structure of the molars of *Elephas Clifti*, from the Pliocene of India, Burma, and Japan, which is the most generalised species of the



Fig. 1279.—*Elephas Clifti.* The first left upper true molar; from Burma. One-half natural size. (After Clift.)

genus, is shown in fig. 1279; where it will be seen that the ridges are low and roof-like, and that the cement is confined to the bottom of the intervening valleys. The molars of this species (in which premolars were developed), it will be seen, are but one step in advance of those of the Tetralophodont Mastodons. In other species of this group, like *E. in-*

signis, the ridges of the molars (fig. 1280[1]) become more numerous, and somewhat higher; while the intervening valleys are more or less completely filled with cement. The number of ridges in the cheek-teeth of this species may be represented by the formula $Mm.\ \frac{2.(5-6).7}{2.5.(7-9)}$, $M.\ \frac{(7-8).(7-8).(9-11)}{(7-10).(8-12).(9-13)}$. Allied species are *E. bombifrons* and *E. ganesa*, which are found in the Pliocene of India and the countries to the eastward as far as Japan.

In the second, or *Elephantine*, group, the specialisation of the molars becomes greater; in all the species the ridges are so tall that they assume the appearance of plates, but there is great varia-

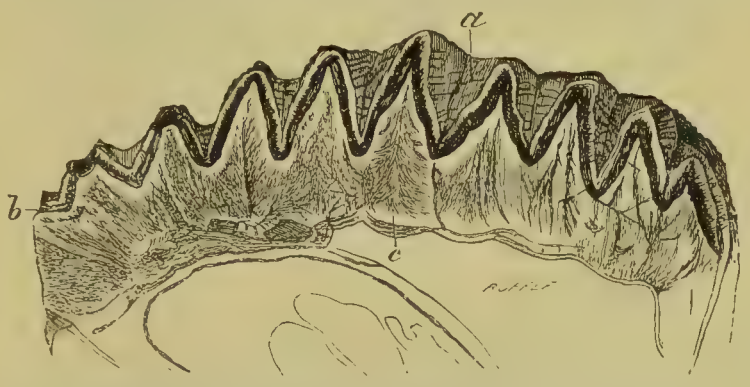


Fig. 1280.—*Elephas insignis*. Vertical and longitudinal section of the third left upper true molar; from the Pliocene of the Siwalik Hills. One-third natural size. *a*, Cement; *b*, Enamel; *c*, Dentine. (After Falconer and Cautley.)

tion in respect to their height and number; those of the less specialised forms not being more numerous than in *E. insignis*. The cement always completely fills the interspaces between the ridges, and in the higher forms these interspaces are extremely narrow.

One of the least specialised members of this group is *Elephas planifrons*, from the Pliocene of Northern India, of which the section of an upper molar is represented in fig. 1281. In the teeth of this species the number of the ridges is nearly the same as in *E. insignis*; but, as will be seen from the figure, the ridges have become much taller and thinner, and the valleys are completely filled up with cement. It results from this structure that when the crown of the tooth has become well worn (as in the anterior half of fig. 1282), its grinding aspect will present a nearly flat surface marked by a series of transversely elongated raised disks of enamel, each enclosing an islet of dentine. This structure, which is still better exemplified in the more-worn molar of the closely allied *E. meridionalis* (fig. 1283), of the Upper Pliocene of Tuscany and the Norfolk "Forest-bed," is admirably adapted for the attrition of vegetable matter owing to the inequalities produced on the surface, due to the variation in

[1] In this figure, as well as in fig. 1281, the tooth is turned the wrong way upwards.

the density of the different layers of which the tooth is composed. The enamel-disks of both the species under consideration are, when partially worn, generally expanded in the middle, and are often interrupted in their course across the crown; in the European species the enamel itself being thrown into a series of fine plications, or crenulations. Both *E. meridionalis* and *E. planifrons* attained gigantic dimensions. the height



Fig. 1281.—*Elephas planifrons*. Vertical and longitudinal section of the second upper true molar; from the Pliocene of the Siwalik Hills. One-third natural size. Letters as in fig. 1280. (After Falconer and Cautley.)

of some individuals of the former being estimated at upwards of fifteen feet, while a fair average height of males of the existing Indian species is not greater than nine feet. *E. planifrons* is remarkable as being the only member of the Elephantine group in which premolars were developed. Somewhat more specialised, both in regard to the height and number of the ridges of the cheek-teeth, and also in the elevation of the vertex of the cranium, is *E. hysudricus*, of the Pliocene Siwaliks of India, which may perhaps have been the ancestor of the existing species of

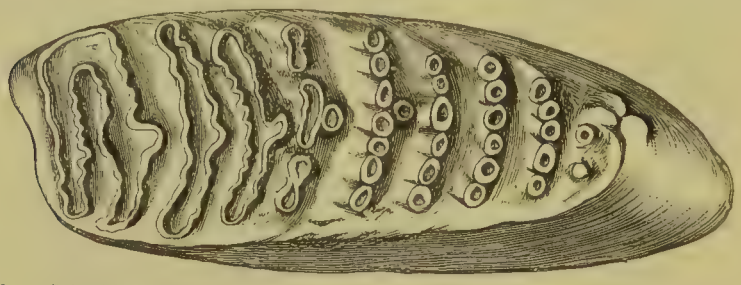


Fig. 1282.—Grinding surface of upper molar of *Elephas planifrons*, one-third natural size; from the Pliocene of India. (After Falconer and Cautley.)

that country. In *E. antiquus*, of the Pleistocene of Europe, we have a species with the ridges of the cheek-teeth somewhat more numerous than in the last form, although less so than in *E. primigenius*: their number being represented by the formula *Mm.* $\frac{(2-3).(5-7).(8-11)}{3.(6-8).(9-11)}$ *M.* $\frac{(9-12).(12-13).(15-20)}{(11-12).(12-13).(16-21)}$. The molars (fig. 1284) are usually relatively narrow, and there is very generally (especially in the lower jaw)

median expansion of the worn enamel-disks of the ridges, which thus approach a lozenge-shape. The range of this species in England does not extend northwards of Yorkshire, and it goes as far south as Algeria,

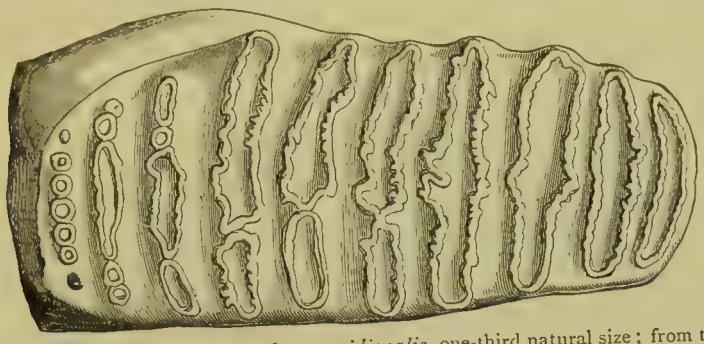


Fig. 1283.—Upper molar of *Elephas meridionalis*, one-third natural size; from the Upper Pliocene of Tuscany.[1]

where the allied *E. atlanticus* is also found. From the molars of *E. antiquus* there is but a step to those of the existing African Elephant (fig. 1285), in which the enamel-disks assume a still more decided lozenge-

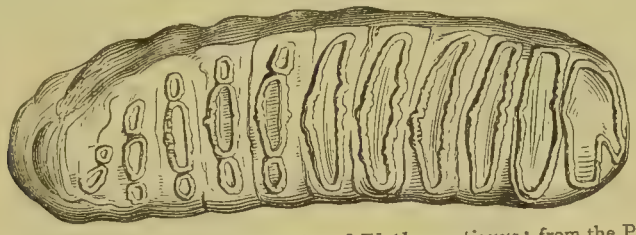


Fig. 1284.—The second right lower true molar of *Elephas antiquus;* from the Pleistocene of England. One-third natural size.

shape; and the small *E. mnaidriensis* and *E. melitensis*, of the Pleistocene cavern and fissure-deposits of the Maltese and neighbouring islands, are more or less closely allied forms. The height of the smallest indi-



Fig. 1285.—A right upper true molar of *Elephas africanus;* Recent. Africa. One-third natural size.

viduals of the last-named, or "Pigmy Elephant," is estimated as not greater than three feet. Another peculiar Elephant is *E. namadicus*, from the Pleistocene of the Narbada Valley, in Western India, and Japan,

[1] The hinder part of this tooth is to the left; the position of the preceding figure being the reverse.

which is closely allied in dental characters to *E. antiquus*, although distinguished by a very prominent overhanging ridge on the frontals. Here we may also mention *E. Columbi*, of the Pleistocene of Central and North America, and *E. armeniacus* from Armenia; the former being intermediate in the structure of its teeth between *E. antiquus* and *E. indicus*, and the latter between *E. primigenius* and *E. indicus*. It is, however, not improbable that *E. Columbi* is only a variety of the Mammoth. Lastly,



Fig. 1286.—A half-worn third left upper true molar of the Mammoth (*Elephas primigenius*), viewed from the grinding surface; from the Pleistocene of Europe. One-third natural size.

we have the Mammoth (*E. primigenius*), in which the number of ridges in the molars is represented by the high figures *Mm.* $\frac{(3-4).(6-9).(9-12)}{(3-4).(6-9).(9-12)}$, *M.* $\frac{(9-15).(14-16).(18-27)}{(9-15).(14-16).(18-27)}$. "The incisors are usually long, spiral, and not very thick near the alveolus; they are, however, subject to great variation. The molars (fig. 1286) are relatively wide in proportion to their length; their ridges are narrow and closely packed, with the cement, enamel, and dentine very thin; the plication of the enamel is usually slight; the worn dentine-disks are very narrow; and the crown is usually characterised by the extreme flatness of its wear. Variations are common, and those molars in which the ridges are thicker and less numerous, and the enamel is more plicated, approach very closely to certain examples of *E. antiquus*. The existing Indian species presents a close approach in dental and skeletal structure, but the molars are decidedly of a less specialised type, and thereby indicate that the living species is not a descendant of the Mammoth." This animal was covered with a thick woolly coat, and also with an outer covering of long hair, by which means it was protected from the climatal rigours of the northerly regions over which it once roamed. Remains of the Mammoth have been found in Northern Europe, Asia, and America; and in the frozen soil of the banks of the Siberian rivers numerous carcasses have been

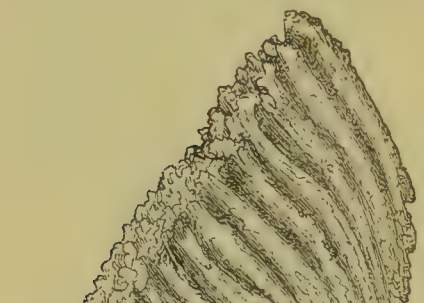


Fig. 1287.—Lateral view of a half-worn upper true molar of the Mammoth. About one-third natural size.

found with the dried flesh, skin, and hair preserved; the skeleton of one of these specimens, with portions of the skin still adhering to it, being preserved in the Museum at St Petersburg (fig. 1288). The Mammoth was essentially northern in its distribution, apparently not passing southwards of a line drawn through the Pyrenees, Alps, the



Fig. 1288.—Skeleton of the Mammoth. Greatly reduced. Portions of the integument still adhere to the head, and the thick skin of the soles is still attached to the feet.

northern shores of the Caspian, Lake Baikal, Kamschatka, and the Stanovi Mountains. Its remains occur in the Norfolk "Forest-bed," and from this date the species existed right through the glacial epoch, and was well known to the primitive human inhabitants of Northern Europe, as is testified by its portrait drawn on a fragment of its own tusk by one of these early hunters.

Finally, it should be mentioned that a portion of a tusk of a Proboscidean, said to have been obtained from the Pleistocene of Australia, has been described as *Notelephas*. There are, however, no characters in this specimen to indicate its right to generic distinction, and its reputed origin must be looked upon with great suspicion.

Group Tillodontia.—Here may be noticed a remarkable group of Mammals from the Lower Eocene, of which the position is still unsettled. They are regarded by Professor Marsh as constituting a distinct order; while Professor Cope subdivides them into Tillodontia and Tæniodontia, and includes them in his order Bunotheria. A suggestion has also been made of affinity with the Edentates. These Mammals, as will be gathered from the characters mentioned below, present certain characters common to the Ungulata, Rodentia, and Carnivora, but to include them in either one of those orders would render it impossible to give anything approaching to a definition of the order so enriched. Putting aside the suggestion of Edentate affinities as requiring further evidence, the characters presented by the Tillodonts harmonise with the view that both the Ungulates and Rodents have been derived from a primitive Carnivorous stock.

Family Anchippodontidæ.—The genus *Anchippodus* (*Trogosus*), with which *Tillotherium* (fig. 1289) is closely allied or identical, is

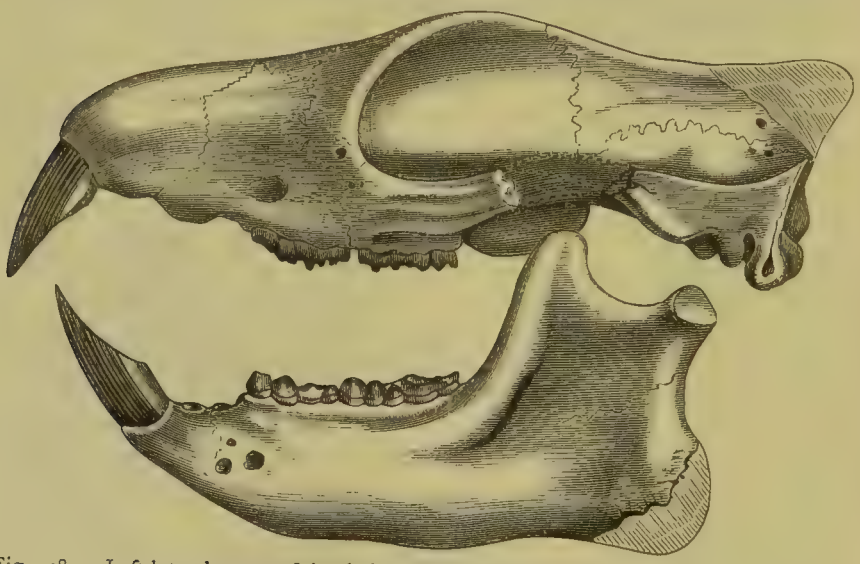


Fig. 1289.—Left lateral aspect of the skull of *Tillotherium fodiens*; from the Lower Eocene of North America. One-fourth natural size. (After Marsh.)

from the Lower Eocene of North America, and apparently has the dental formula $I.\frac{2}{2}$, $C.\frac{1}{1}$, $Pm.\frac{3}{4}$, $M.\frac{3}{3}$. The lower cheek-teeth

resemble those of *Palæotherium*, but the upper true molars are of the triangular tritubercular type. The first pair of incisors is small, but the second is large and scalpriform, with persistent pulps like the incisors of the Rodents. In many respects the skeleton approximates to that of the Creodonta; the femur has a third trochanter; the feet were five-toed, with the whole sole applied to the ground, and having ungual phalanges similar to those of the Bears. The brain-cavity is of small size, and the cerebral hemispheres did not extend over the cerebellum or the olfactory lobes. The orbits are not complete, but open into the temporal fossæ. Clavicles were probably present.

Family Platychœropidæ.—The type genus of this family is *Platychœrops* (*Miolophus*), from the London Clay, to which the

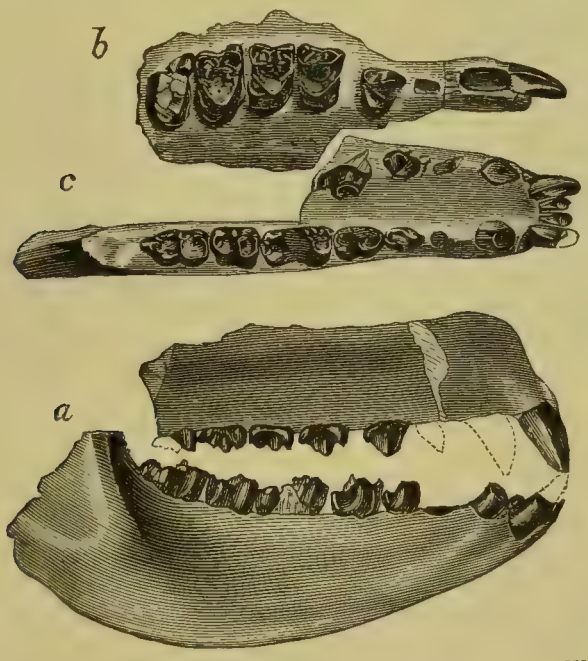


Fig. 1290.—*Esthonyx Burmeisteri*.—The palate and mandible; from the Wasatch Eocene of Wyoming, U.S.A. Two-thirds natural size. *a*, Lateral view of part of cranium and mandible; *b*, Oral view of right half of palate; *c*, Oral view of mandible. (After Cope.)

North American *Esthonyx* (fig. 1290) appears to be allied. In the latter the first upper and the second lower incisors are scalpriform, but do not grow from persistent pulps; the dental formula is $I.\frac{2}{3}$, $C.\frac{1}{1}$, $Pm.\frac{3}{3}$, $M.\frac{3}{3}$ If *Esthonyx* be not allied to *Platychœrops*, the former must constitute the type of a family, which should be known as the *Esthonychidæ*. The genus *Psittacotherium*, of which the family position is uncertain, has the mandible of great

depth, and the lower molars with transverse ridges; both the first and second lower incisors being scalpriform, and growing from persistent pulps; and the genus may be regarded as connecting *Anchippodus* with *Calamodon*. The lower dental formula appears to be *I.* 2, *C.* 1, *Pm.* 3, *M.* 3; and two species are known from the Puerco, or lowest, Eocene of New Mexico.

Family Calamodontidæ.—In *Calamodon*, the type genus of this family (the Tæniodontia of Professor Cope), the lower jaw resembles that of *Psittacotherium;* there are three lower incisors, of which the second and third are scalpriform, and have their anterior surfaces faced with enamel; and the cheek-teeth are five in number, but cannot be differentiated into premolars and true molars. There is no diastema, and the cheek-teeth approximate to those of the Rodents in their massive squared crowns, and have also been considered to show resemblances to those of the Edentates. The second lower incisor is much larger than either of the others, and the mandibular condyle is transversely elongated. Professor Cope, as will be noticed below, regards this group, and more especially *Psittacotherium*, as close to the ancestral types of the Rodentia, and has also suggested their alliance to the ancestors of the Edentates; *Calamodon* is from the Wasatch or Middle Eocene.

Family Stylinodontidæ.—Professor Marsh has proposed this family name for the North American Tertiary genus *Stylinodon*, in which the molars grew from persistent pulps like those of the Edentates.

CHAPTER LXII.

CLASS MAMMALIA—continued.

Orders Rodentia and Carnivora.

Order VII. Rodentia.—The Rodents form one of the best-defined orders of the whole class, and are readily characterised by the absence of canines, and their chisel-like (scalpriform) incisors (of which there is only a single lower pair), separated by a long diastema from the cheek-teeth (fig. 1298), and of which generally only the anterior face is coated with enamel. The dentition is diphyodont and heterodont; the incisors grow from persistent pulps, and the cheek-teeth may be either rooted or rootless. The crowns of the latter are entirely adapted for grinding, and are very frequently (fig. 1292) complicated by deep infoldings of enamel. The premolars are very generally either $\frac{1}{1}$ or $\frac{0}{0}$, and the true molars $\frac{3}{3}$. The premaxillæ are large; the zygomatic arch is complete, the middle portion being generally formed by the jugal; the orbit is confluent with the temporal fossa; there is a long diastema; and the condyle of the mandible is antero-posteriorly elongated, and, through the absence of a postglenoid process in the cranium, capable of a backwards and forwards motion. The feet are generally partially or entirely plantigrade, and usually furnished with five unguiculate digits. More or less complete clavicles are present, and the acromion of the scapula frequently has a long recurving process. All the existing forms are of comparatively small size, and most of them are of terrestrial habits. The feature of hypsodontism, which we have already noticed under the head of the Ungulata, attains its greatest development in this order; its final stage being the production of rootless cheek-teeth.

That the Rodents are connected in some manner with the more

generalised Ungulates is quite evident; and Professor Cope would derive them from Tillodontia, allied to *Calamodon* and *Psittacotherium*, and accordingly considers that their lower incisors and the corresponding upper ones represent the second of the three typical pairs. This view is, however, not supported by the dentition of the young of the *Leporidæ*. The *Leporidæ* show certain points of resemblance to *Typotherium* among the Toxodontia; while in the entire order distant affinities are indicated to the Proboscidea, as is shown by the characters of the teeth, the acromion of the scapula, and the position of the jugal.[1]

This order is well known from the period of the Upper Eocene (Oligocene), while *Decticadapis* apparently carries it back to the commencement of the Tertiary. It has not suffered very greatly by the extinction of family types at the present day, although all the gigantic forms have completely disappeared.

Suborder 1. Duplicidentata.—This suborder is characterised by the number of the incisors, which in the adult are $\frac{2}{1}$, but at birth $\frac{3}{1}$. The outer pair of upper incisors is very soon lost, the second pair being of small size, and placed directly behind the large first pair. The incisive palatal foramina are large and confluent; the fibula is anchylosed to the tibia, and articulates with the calcaneum. The enamel-coat of the incisors is not entirely confined to their anterior surface.

Family Leporidæ.—In this family the number of cheek-teeth is *Pm.* $\frac{3}{2}$, *M.* $\frac{3}{3}$; these teeth being rootless, with transverse enamel-folds. The clavicles are imperfect, and the fore limbs shorter than the hind ones. This family includes at the present day only the cosmopolitan genus *Lepus*, comprising the Hares and Rabbits. Existing species of that genus have left their remains in the caves of Europe and Brazil; while extinct ones are found in the Upper Pliocene of France (*L. Lacosti*), in the Siwaliks of India, and in the John Day Miocene of North America. *Palæolagus* from the Miocene of the latter country is closely allied to *Lepus;* while *Panolax* from equivalent strata in New Mexico has only a single plate in the first upper true molar.

[1] The Rodents differ from the Proboscidea in having a discoidal in place of a zonary placenta; but it has recently been found that in the Mouse there are traces of this discoidal placenta having been derived from an earlier zonary one. The zonary placenta of the Proboscidea is evidently a specialisation of the diffused placenta of the other Ungulates; and we can now see how a further specialisation of the zonary placenta results in the discoidal one of the Rodents, Insectivores, and Primates.

Family Lagomyidæ.—This family includes very small Hare-like Rodents, with short ears, complete clavicles, and the fore limbs not shorter than the hinder. They are very characteristic of the mountains of Central and Northern Asia, but also occur in those of Europe and North America. Their cheek-teeth resemble those of *Lepus*, but the premolars are never more than $\frac{2}{2}$, and may be reduced to $\frac{1}{1}$. Those extinct forms in which the premolars are $\frac{2}{1}$ have been separated from the existing genus *Lagomys* as *Myolagus*, and those with only *Pm.* $\frac{1}{1}$ as *Titanomys*, but it appears preferable to include all these variations in the type genus. The Pleistocene of Europe contains remains of some existing and some extinct (*L. sardus*) species, and the genus is well represented in the Tertiaries of the Continent as far down as the Lower Miocene (Upper Oligocene); the species of the latter horizon being *L. visenoviensis* (fig. 1291), the type of *Titanomys*. Fossil remains of this genus have also been found in the Pleistocene cave-deposits of Port Kennedy in the United States.



Fig. 1291.—Left ramus of the mandible (outer view) of *Lagomys visenoviensis*; from the Lower Miocene of Europe.

Suborder 2. Simplicidentata.—The incisors are always $\frac{1}{1}$, and have the enamel confined to their anterior surface. The incisive foramina on the palate are of moderate size; and the fibula does not articulate with the calcaneum.

Family Caviidæ.—This and the following five families compose the section *Hystricomorpha*. The *Caviidæ*, which are now exclusively confined to America, have four anterior and three posterior digits, and in the existing genera the crowns of the molars are divided by enamel-folds into transverse lobes; the number of the cheek-teeth being *Pm.* $\frac{1}{1}$, *M.* $\frac{3}{3}$. *Cavia*, in which the tail is absent, is represented by remains of several existing species in the Pleistocene of the Brazilian caves; while *Contracavia* is a much larger extinct type from the infra-Pampean of South America. *Microcavia*, again, from the Pleistocene of Argentina, presents characters connecting it with *Cavia* and the following genus. *Dolichotis* (or *Cerodon*), in which there is a short tail, is also represented in the South American Pleistocene; two species being extinct, while the third (*D. antiqua*) may be identical with the living form. Here may be provisionally placed the genera *Issiodoromys* and *Nesocerodon* from the Quercy Phosphorites and Lower Miocene of France, which

are regarded by recent authorities as related to *Dolichotis*, although formerly placed in the *Theridomyidæ*. The crowns of their molars are vertically divided by enamel-folds into two heart-shaped lobes. *Hydrochochœrus*—the largest living Rodent—is represented in the Brazilian cave-deposits by a species probably identical with the living Capybara, and also in the Pleistocene of Buenos Ayres by an extinct one estimated to have attained a length of five feet, and by a third (*H. magnus*) of still larger dimensions. An extinct species has also been obtained from the Pleistocene of South Carolina; and another from the infra-Pampean deposits of Parana. From the latter deposits other forms supposed to be more or less nearly allied to the existing genus have received the names *Cardiatherium*, *Procardiatherium*, *Cardiomys*, and *Cardiodon*; the latter name had, however, been previously applied to a Sauropodous Dinosaur,[1] and is therefore inadmissible.

Family Dasyproctidæ.—In this South and Central American family the number of the cheek-teeth is the same as in the last; and these teeth are also semi-rooted, but their crowns have external and internal enamel-folds (fig. 1292); and the incisors are long. The type genus *Dasyprocta* is represented by numerous forms in the Pleistocene of the Brazilian caves; while a *Cœlogenys* occurring in the same deposits is probably identical with the living Paca (*C. paca*).

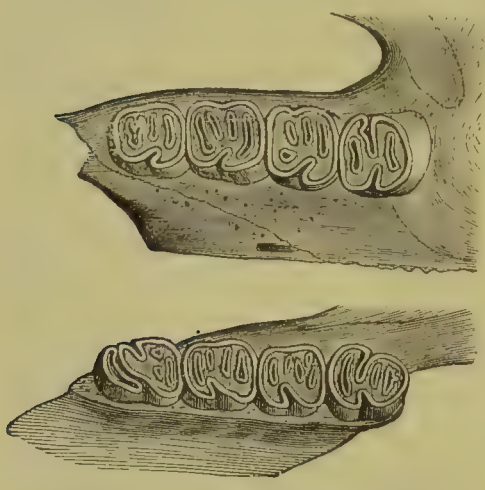


Fig. 1292.—Palatal view of the right upper and lower dentition of *Dasyprocta*. Recent. America. The tooth in each jaw on the right side of the figure is the premolar.

Family Chinchillidæ.—This third family of American Rodents has the same dental formula as the last, but the molars have continuous enamel-folds extending completely across their crowns, and the hind limbs are much elongated. The genus *Lagostomus* is represented in the South American Pleistocene by the existing Vischaca (*L. trichodactylus*), as well as by some extinct forms. *Megamys* from the infra-Pampean deposits of Patagonia and Parana is the largest representative of the order yet known; its bulk being estimated as equal to that of an Ox. Several species have been described, one of which is the type of *Potamarchus* of Dr Burmeister. Allied genera from the South American

[1] See page 1177.

deposits are *Epiblema* and *Tetrastylus;* one species of the latter having been originally referred to *Theridomys.*

Family Hystricidæ.—The Porcupines are well characterised by their spiny covering. The number of their cheek-teeth is the same as in the preceding families; and these teeth have both external and internal enamel-folds. An extinct species of the American genus *Synœtheres* occurs in the Pleistocene of the Brazilian caves, while a species of the other American genus *Erithizon* is recorded from cave-deposits in Pennsylvania. *Atherura* is found in the Pleistocene of Southern India. *Hystrix* occurs in the Pleistocene and Pliocene of India; in Europe from the Upper Pliocene of the Val d'Arno down to the Middle Miocene, and perhaps to the Quercy Phosphorites; while in North America it is represented both in the Pliocene and the White River Miocene. Finally, *Mylagaulus* from the Miocene of the United States may be allied either to *Hystrix* or *Dasyprocta* (Agouti).

Family Castoroididæ.—The gigantic *Castoroides*, of the Pleistocene of the United States, is now generally regarded as entitled to represent a distinct family although originally placed in the *Castoridæ.* Although presenting certain cranial features recalling *Castor*, its dentition comes nearest to that of *Chinchilla* and *Hydrochœrus.* The extinct genera *Loxomylus* and *Amblyrhiza*, from the Pleistocene of the Antilles, may probably be included in the same family; their dentition presenting many resemblances to that of *Chinchilla. Castoroides* must have attained the dimensions of a Bear.

Family Octodontidæ.—With the exception of *Ctenodactylus* the number of the cheek-teeth in this Ethiopian and South American family[1] is the same as in the *Hystricidæ;* these teeth having both external and internal enamel-folds, with either imperfect or perfect roots. In the South American Pleistocene we meet with existing and a few extinct species of the genus *Carterodon*, which is characterised by the broad and grooved incisors, and also of *Myopotamus* (Coypu), *Echinomys*, *Loncheres*, *Phyllomys*, and *Ctenomys.* Other forms from the South American Tertiaries allied to the latter have been named *Phloramys* and *Pithanotomys;* while *Morenia* and *Orthomys*, from the infra-Pampean beds of Parana, and *Tribodon*, from Monte Hermosa, are regarded as related to *Myopotamus.* The extinct *Pellegrinia*, from the Sicilian Pleistocene, may be allied both to the Ethiopian *Ctenodactylus* and the American *Octodon.*

Family Theridomyidæ.—This extinct family appears to be most nearly related to the preceding although connected by *Archæomys* with the *Chinchillidæ.* The cheek-teeth number *Pm.* $\frac{1}{1}$, *M.* $\frac{3}{3}$. In

1 One species of *Echinomys* occurs in Central America.

Theridomys (fig. 1293, B) they are rooted, and have three or four re-entering enamel-folds, which form isolated disks on the worn crowns. This genus occurs in the Lower Miocene and Upper Eocene of Europe; while *Syllophodus* of the North American Miocene is closely allied. *Protechinomys* of the Lower Miocene and Upper Eocene of France has rooted cheek-teeth with crowns very like those of *Theridomys* and the living *Echinomys* (*Octodontidæ*); while *Archæomys* of the same deposits has the teeth devoid of roots, with their enamel-folds continuing across the crown, and dividing it into laminæ (fig. 1293, A). *Trechomys* is a fourth allied genus from the Quercy Phosphorites, having cheek-teeth somewhat like those of *Theridomys*, but with laterally-compressed crowns.

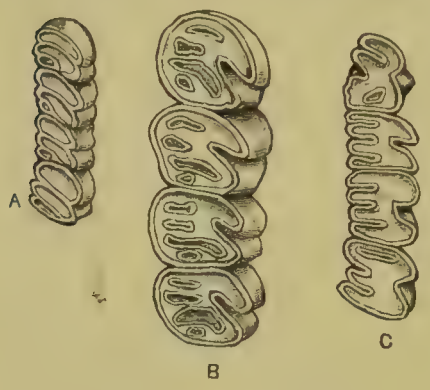


Fig. 1293.—A, Left lower cheek-teeth of *Archæomys*; B, Left upper cheek-teeth of *Theridomys*; C, Left lower cheek-teeth of *Chalicomys*. A and B enlarged. In B the uppermost, and in A and C the lowest, tooth is the premolar.

Family Dipodidæ.—This and the four following families are embraced in the section Myomorpha. In the *Dipodidæ* (Jerboas) remains of the existing *Alactaga jaculus* occur in the Pleistocene of Europe, and those of *Zapus* (*Jaculus*) *hudsonianus* in the corresponding beds of North America; while a species of *Platycercomys* has been recorded from the Pleistocene of Northern Asia. The so-called *Dipöides* of the Tertiary of Würtemberg is probably a *Chalicomys*.

Family Geomyidæ.—The American Pouched-Rats, in which the cheek-teeth are *Pm.* $\frac{1}{1}$, *M.* $\frac{3}{3}$, are represented by species of the type genus *Geomys* in the Pleistocene and Pliocene of North America, and also by one existing species of *Thomomys* in the Pliocene of Oregon. In the Miocene of the United States two extinct genera are also met with, of which *Entoptychus* is allied to *Thomomys*, and has rootless molars and broad incisors; while *Pleurolichus* has rooted molars and the incisors without grooves, like those of the allied existing genus *Heteromys*.

Family Spalacidæ.—This Old World family comprises burrowing Rodents, with large incisors, and rooted molars having re-entering enamel-folds. The only fossil representative is a *Rhizomys*, from the Siwalik Hills of India, which appears to be closely allied to the living forms; all of which are characterised by the absence of premolars.

Family Muridæ.—The *Muridæ* form by far the largest family

of the order, and are mainly characterised by certain peculiar features of the skull. With the exception of *Sminthus*, premolars are wanting; and the true molars, except in the Australian *Hydromys* and *Xeromys*, where they are reduced to $\frac{2}{2}$, are $\frac{3}{3}$ in number; while the lower incisors are laterally compressed. The molars may be rooted or rootless, and either brachydont and tuberculate, or hypsodont with re-entering enamel-folds. This family may be divided into several subfamilies. Of these the *Cricetinæ* have the cusps of the upper molars arranged in two longitudinal series; these teeth being either rooted or rootless. This subfamily, which is now the dominant one in America, but was formerly largely developed in the Old World, where it is still found, appears to represent the archaic or generalised type of the family. In the Voles, or the more specialised Cricetines, the cusps of the molars have become modified into triangular prisms alternately arranged (fig. 1294), and

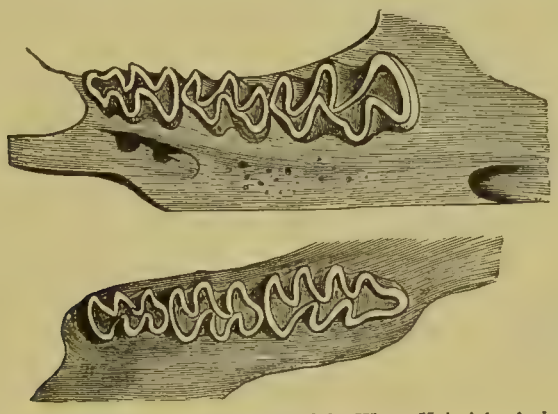


Fig. 1294.—The left upper and lower molars of the Water-Vole (*Arvicola amphibius*). Enlarged.

the roots are generally not developed, so that the crowns are hypsodont. *Siphneus*, which connects this family with the preceding, is found at the present day in Central Asia, and is represented by a living species in the Pleistocene of the Altai, and by another, which is extinct, in the Pliocene of Northern China. Of *Arvicola* (*Microtus*[1]), and *Lemmus* (including *Cuniculus*), there are numerous species in the Pleistocene of Europe, some of which are identical with living forms, while others are extinct; the former genus being also represented in the Forest-bed and the Coralline Crag. The allied *Fiber*, of North America, occurs also in the Pleistocene of the same country. In the typical or less specialised forms, the molars usually

[1] This name, as being earlier than *Arvicola*, is adopted by several recent writers.

have simple cusps, and are rooted. *Paciculus*, from the Miocene of the United States, is allied to the next genus, but has enamel-folds to the molars. *Neotoma* is represented by a species in the Pleistocene of the Pennsylvanian caves, which is perhaps not distinct from the living Florida-Rat. The genus *Cricetus*, typically represented by the European Hamsters, is taken by Mr O. Thomas to include the American *Hesperomys*. It is represented sparingly in the Pleistocene of Europe; but it is probable that *Cricetodon* (*Decticus*), which ranges from the Quercy Phosphorites to the Middle Miocene of France, cannot be generically separated. In America fossil forms occur abundantly in the Brazilian cave-deposits, where they have been described as *Hesperomys;* and it is probable that we must include in the same large genus (*Cricetus*) the so-called *Eumys* of the Miocene of North America. The subfamily *Deomyinæ* is only known by *Deomys*, of the Congo Valley, which has upper molars intermediate in structure between those of the preceding and following subfamilies. The *Murinæ*, or more specialised Mice, are mainly characteristic of the Old World, and do not date back far in time. Their upper molars have the cusps or tubercles arranged in three longitudinal rows and well-developed roots. *Mus*, or the closely allied *Acomys*, is first known from the Pliocene Pikermi beds, and thence is found through the Pleistocene of Europe. The Australian genera *Hapalotis* and *Mastacomys* are represented by existing species in the cave-deposits of that country. The Indian *Phlæomyinæ*, having broad upper incisors, and rooted molars with transverse laminæ, are represented in the Pleistocene of *Madras* by two species of *Nesocia* identical with those now inhabiting the same area. The *Gerbillinæ* also have laminated molars (fig. 1295), but the upper incisors are narrow and the hind limbs elongated. The existing *Gerbillus indicus* occurs fossil in the Madras caves. The last molar in both the upper and lower jaws of this genus has only a single transverse lamina, as shown in the figure. Lastly the *Sminthinæ*, in which there is a premolar in the upper jaw, are represented by the existing *Sminthus vagans* in the Pleistocene of Europe.



Fig. 1295.—The left ramus of the mandible, and the lower molars (enlarged) of *Gerbillus indicus;* from a cave in Madras.

Family Myoxidæ.—In the Dormice the number of the cheek-teeth is *Pm.* $\frac{1}{1}$, *M.* $\frac{3}{3}$; these being rooted, with complex enamel-folds. For palæontological purposes all the forms may be included in *Myoxus*, which commences in the Paris gypsum and Quercy Phosphorites, and is represented in the Pleistocene of Malta by a

species of the size of the Guinea-pig. The so-called *Brachymys* of the German Miocene appears to be generically the same.

As Myomorpha, of which the affinities are uncertain, may be mentioned *Heliscomys*, of the North American Miocene, in which there are four lower cheek-teeth, and the lower incisors are compressed and grooved; and *Eomys* (or *Omegodon*), from the Quercy Phosphorites, in which the cheek-teeth are *Pm.* $\frac{1}{1}$, *M.* $\frac{3}{3}$. *Colonomys*, from the North American Miocene, also belongs to this section.

Family Castoridæ.—With this family we enter the Sciuro-

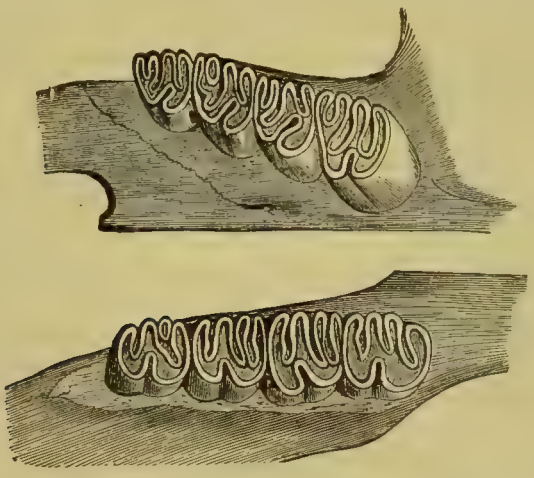


Fig. 1296.—Palatal aspect of the right upper and lower cheek-teeth of the Beaver (*Castor fiber*). The tooth on the right of each figure is the premolar.

morpha, which includes all the remaining Rodents. The Beavers are natatorial Rodents, with *Pm.* $\frac{1}{1}$, *M.* $\frac{3}{3}$; the cheek-teeth being semi-rooted or rootless, with re-entering enamel-folds (fig. 1296). *Castor* is represented by the existing Beaver in the European Pleistocene, and by an allied form in the Pliocene of the Auvergne; and also occurs in the Miocene of North America, where it has been named *Eucastor*. There has been great dispute as to the affinities of the great extinct Beaver (fig. 1297) of the Norfolk Forest-bed and Norwich Crag, but it is regarded by Mr Newton as identical with both *Trogontherium* of the Russian, and *Diobroticus* of the French Pleisto-



Fig. 1297.—Right ramus of the mandible of *Trogontherium Cuvieri*; from the Forest-bed. One-fourth natural size. (After Owen.)

cene. An allied genus is *Chalicomys* (*Steneofiber*), in which the humerus has a foramen, and the molars (fig. 1293, c) are more distinctly rooted, with shallower enamel-folds; it occurs in Europe in the Middle and Lower Miocene, and also in the Miocene of North America; *Palæocastor* from the latter deposits being apparently closely allied.

Family Ischyromyidæ.—*Ischyromys* (with which *Tillomys* is apparently identical) is a North American Miocene genus with *Pm.* $\frac{2}{1}$, *M.* $\frac{3}{3}$; having dental characters of the *Sciuridæ*, but otherwise resembling the *Hystricidæ* and *Caviidæ*, and thus indicating that the sections into which the existing Rodents are divided will not hold good for all the fossil forms. *Pseudotomus* from the White River Miocene is an allied form; while *Sciuromys* of the Quercy Phosphorites is probably also related. *Mysops* of the North American Eocene, according to Dr Schlosser, may be the same as *Ischyromys*. *Gymnoptychus* (p. 1421) may also be allied.

Family Sciuridæ.—In this family the cheek-teeth are usually *Pm.* $\frac{2}{1}$, *M.* $\frac{3}{3}$, but in *Sciurus* the first upper premolar is often absent. The molars are rooted, and, with the exception of *Eupetaurus* of Kashmir, are brachydont; those of the upper jaw usually having triangular or squared crowns, with two or more shallow infolds of

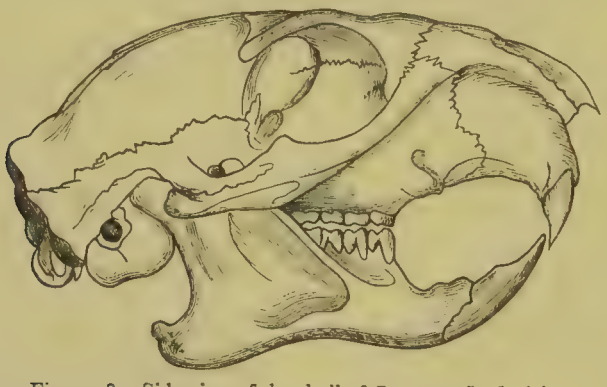


Fig. 1298.—Side view of the skull of *Cynomys Ludovicianus*.

enamel from the outer side (fig. 1299). The Marmots and their allies (fig. 1298) have uncompressed incisors; and the type genus *Arctomys* is represented by the existing *A. marmotta* (fig. 1299) in the Pleistocene of Europe, and by another species in that of North America. *Plesiarctomys* (with which *Sciuravus*, Marsh, and *Paramys*, Leidy, are identical) occurs in the Middle Tertiaries of both Europe and the United States, and connects *Arctomys* with *Sciurus*. *Spermophilus*, or the Sousliks, has both living and extinct

species in the Pleistocene of Europe; while the allied *Plesispermophilus* has been described from the Quercy Phosphorites. Among the Squirrels, of which the living genera have compressed incisors, *Sciurus* itself ranges down to the Quercy Phosphorites in Europe, and in North America occurs in the White River Miocene; the common existing *S. vulgaris* being found in the Norfolk Forest-bed. The recent northern genus *Tamias* occurs in the Pleistocene of Europe and Nebraska; while *Pseudosciurus* and *Sciuroides* are allied extinct genera from the Upper Eocene of the Continent, in both of which the molars are more elongated than in *Sciurus*. *Gymnoptychus*, with $Pm.\ \frac{1}{1}$, $M.\ \frac{3}{3}$, from the Miocene of North America, has more complex molars, and thereby approaches *Pteromys*; while *Meniscomys* (with which *Allomys* is apparently identical), with $Pm.\ \frac{2}{1}$, from the same deposits, presents some resemblances to the American *Haplodontidæ* (which, like the *Anomaluridæ*, are unknown in a fossil state), *Sciurodon* from the Quercy Phosphorites is regarded as a closely allied genus.

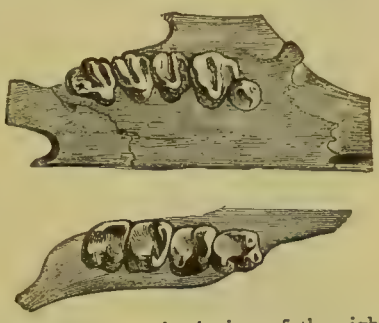


Fig. 1299.—Palatal view of the right upper and lower dentition of the Marmot (*Arctomys marmotta*). Recent and Pleistocene, Europe. The two teeth on the right side of the upper figure are the premolars.

Finally, we may here mention the small *Decticadapis*, of the Lower Eocene of Rheims, which appears to be a Rodent, although its affinities cannot yet be determined.

Order VIII. Carnivora.—Although the existing Carnivora can be defined with fair exactness, yet the fossil forms here included in this order render such definition almost or quite impossible. All the known forms are, however, unguiculate, with never less than four digits to each foot, all of which bear claws; and the pollex and hallux are never opposable. The dentition is diphyodont and heterodont, and (with the exception of the canines of the *Trichechidæ*) the teeth have closed pulp-cavities. The incisors are very generally three in number, the third being the largest; the canines are strong, pointed, recurved, and larger than the incisors; while the first pair of incisors never have an interval between them. The cheek-teeth vary, but are usually compressed in the anterior part of the series; while if the molars are tuberculate, they are not complex and divided into lobes by deep infolds of enamel. The condyle of the mandible forms a transversely elongated half-cylinder, working in a deep glenoid fossa, protected by a large postglenoid process. The

clavicle is never complete, and is frequently absent; the radius and ulna and the tibia and fibula are always distinct; but the scaphoid and lunar of the carpus very frequently coalesce. In a large number of cases the humerus has an entepicondylar foramen. The majority of the species subsist on animal food. In the more specialised types there is a tendency to a reduction in the number of the cheek-teeth, more especially the true molars.

As in the Rodents and the following orders, the manus is susceptible in most cases of the movements of pronation and supination; the head of the radius being accordingly freely movable in the lesser sigmoid cavity of the ulna. The proximal extremity of the latter bone is shown in the accompanying woodcut in order to exhibit the characteristic features obtaining in the unguiculate orders. Some observations on the phylogeny of the order will be found under the head of the Creodonta.

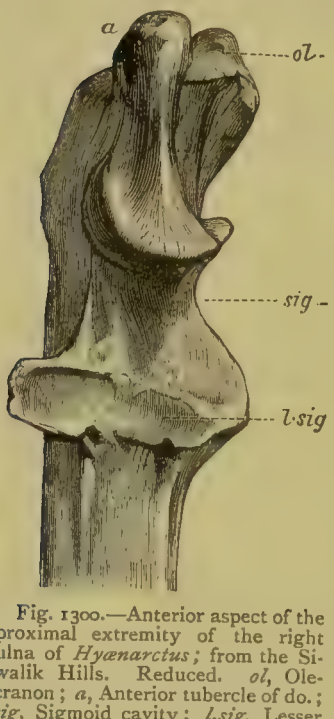


Fig. 1300.—Anterior aspect of the proximal extremity of the right ulna of *Hyænarctus*; from the Siwalik Hills. Reduced. *ol*, Olecranon; *a*, Anterior tubercle of do.; *sig*, Sigmoid cavity; *l.sig*, Lesser do. for head of radius.

The Carnivora are divisible into the suborders Pinnipedia, Carnivora Vera, and Creodonta; the latter being the most generalised.

Suborder 1. Pinnipedia.—This suborder comprises the typical Seals (*Phocidæ*), the Walruses (*Trichechidæ*), and the Eared, or Fur, Seals (*Otariidæ*); all of which mainly differ from the typical Carnivora in points connected with their subaquatic life. The brain is relatively large, with its hemispheres much convoluted, and broad in proportion to their length. The limbs are short, and are each furnished with five digits, which are connected by a web: in the hind feet the first and fifth digits are stouter, and generally longer, than either of the others. In the *Phocidæ* the hind feet when walking are directed backwards parallel to the axis of the body, but in the *Otariidæ*, which are the least aberrant members of the suborder, they are turned forwards. The dentition varies, but at least three kinds of teeth are always present. The canines are long and pointed; the cheek-teeth (fig. 1301), which usually comprise four premolars and one true molar, are not differentiated into carnassials and tuberculars, but are usually sharply pointed and often furnished with fore-and-aft basal cusps, although they are blunt and rounded in the Walrus. There is always a diminution of the incisors below

the typical number of $\frac{3}{3}$. The milk-teeth are very minute, and are either shed or absorbed at a very early date. The structure of the cranium approximates to that of the Bears and their allies. The larger limb-bones present very characteristic features, which enable them to be readily recognised in the fossil state. No fossil forms have been hitherto found which tend to throw any light upon the origin of this suborder; but in the reduction of the number of the incisors, they agree with some of the Creodonts, from which group they may be directly derived.

Family Phocidæ.—The number of incisors in this family varies from $\frac{2}{1}$ in *Cystophora* to $\frac{3}{2}$ in *Phoca* and *Halichœrus*. The best known fossil Seals have been obtained from the Pliocene Crag of Antwerp, and have been referred to the following genera, of which

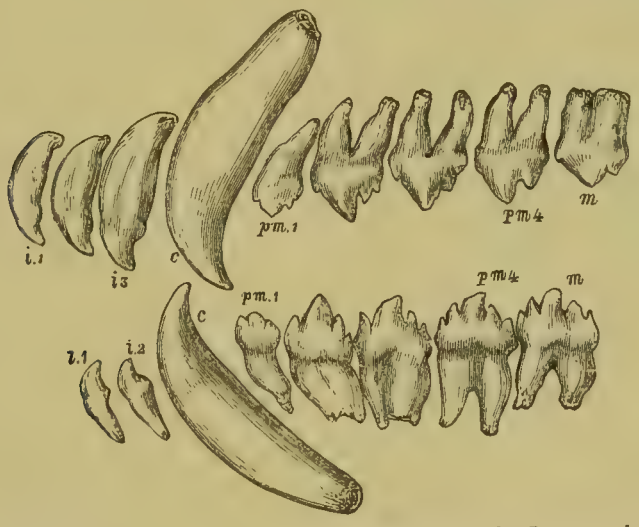


Fig. 1301.—Lateral view of the left dentition of *Phoca*. Reduced. Letters as in fig. 1302.

all but the first are peculiar to the Tertiary, although it may be a question whether all of them are rightly distinguished from existing genera. They comprise *Phoca*, represented by a species allied to the Common Seal (*P. vitulinoides*); *Callophoca* allied to the Greenland Seal (*P. grœnlandica*); *Platyphoca* to the Bearded Seal (*P. barbata*); *Phocanella* to the Ringed Seal (*P. fœtida*); *Gryphoca* to the Grey Seal (*Halichœrus*); *Palœophoca* and *Monatherium* to the Monk Seal (*Monachus*) of the Mediterranean; *Mesotaria* to the Bladder Seal (*Cystophora*); and *Prophoca* which does not appear closely allied to any existing form. Remains of *Phocidæ* in other formations are rare; but a species provisionally referred to the type

genus has been obtained from the Miocene of Malta, while other forms occur in the Pliocene of the Crimea and elsewhere. Remains from the Miocene of Virginia have been described under the name of *Phoca Wymani*, and others from the Pliocene of South Carolina have likewise been referred to the same genus.

Family Trichechidæ.—The Walruses, which are in some respects intermediate between the other two families, are readily distinguished by their enormous upper canines. The existing Arctic *Trichechus rosmarus* occurs fossil in the Norfolk Forest-bed, and an allied species, *T. Huxleyi*, in the Red Crag; while the names *Alachtherium* and *Trichechodon* have been applied to closely allied, if not generically identical, forms from the Belgian Crag.

Family Otariidæ.—This family, in which the number of the incisors is invariably $\frac{3}{2}$, is almost unknown in a fossil state, although some writers have considered that certain genera here included in the *Phocidæ* should be referred to it. Remains of existing species of the type genus *Otaria* have, however, been obtained from Prehistoric or Pleistocene beds in New Zealand, and also from the Pleistocene of South America.

Suborder 2. Carnivora Vera.—In the typical Carnivora the brain is relatively large, and the hemispheres are elongated, and always marked by three or four folds. The fore limbs never have the first digit, or the hind limbs the first and the fifth digits longer than all the rest. There is always a more or less distinctly defined *carnassial* tooth in each jaw; the teeth in front of such carnassial being always more or less compressed and pointed, while those behind the same are broad and tuberculated. And it appears from the dentition of the suborder Creodonta that these tuberculated posterior teeth are the most specialised. The upper carnassial (p^4, fig. 1302), as being the hindmost of those teeth which have milk predecessors, is reckoned as the last premolar; and it usually consists of an outer compressed blade, generally furnished with two (fig. 1302), but occasionally (fig. 1325) with three cusps or lobes, and of an inner tubercle (fig. 1325). This tubercle is generally placed near the anterior extremity of the crown, and is of medium size; but in some instances, as in *Machærodus* (fig. 1334), it may be almost absent, while in others, as in the Otters (fig. 1303), it attains a great development. The lower carnassial (m^1 in the mandible of fig. 1302), as the most anterior of the teeth without milk predecessors, is reckoned as the first of the true molar series. Typically, the crown of this tooth (fig. 1302) consists of an anterior blade, composed of two compressed cusps or lobes, and an inner cusp (fig. 1318), and of a hind talon. In the Wolf (fig. 1302) all these elements are well developed; but sometimes, as in *Felis*

(fig. 1331), both the inner cusp of the blade and the talon may be entirely wanting; or, again, the talon, as in *Ursus* (fig. 1309), may attain excessive development, and the blade be proportionately reduced; the cusps or lobes of the latter being in such cases placed obliquely.

Although the foregoing terms are those generally used in describing the carnassial teeth, a few words may be said as to the serial homology of their cusps. Thus, in the normal type of upper carnassial with two



Fig. 1302.—Outer lateral view of the left dentition of the Wolf (*Canis lupus*). Reduced. *i*, Incisors; *c*, Canine; *p*, Premolars; *m*, True molars.

lobes to the blade (fig. 1318, *pm.* 4), it appears that the inner tubercle represents the protocone of the tritubercular type (p. 1275), the first lobe of the blade corresponding to the paracone, and the second to the metacone. In those forms with a trilobed blade (fig. 1325), the anterior lobe is a superadded element not found in the primitive type. In the lower carnassial (compare fig. 1145, p. 1275) the posterior lobe of the blade, which is really external, is the protoconid; the anterior lobe (paraconid) and the inner cusp (metaconid) are both internal; while the talon is the hypoconid.

With very few exceptions, the incisors are $\frac{3}{3}$ in number. The digits are nearly always furnished with long, sharp, and more or less curved claws, which in the true Cats (*Felis*) can be retracted into protecting bony sheaths. In some genera, like *Ursus*, the whole of the sole of the foot is applied to the ground in walking (*plantigrade*), while in others, like *Canis*, only the terminal digits are so used (*digitigrade*). As a feature of some importance in this suborder,

mention must be made of the *alisphenoid canal*, which is a short bony channel situated in the alisphenoid bone immediately on the outer side of the pterygoid. The existing representatives of this suborder have been divided into three sections—the Arctoidea, Cynoidea, and Æluroidea; but extinct forms show such a complete transition between the three that it is impossible to adopt any divisions of higher rank than families, and scarcely any two writers agree as to the limits of the latter. It is, moreover, very doubtful whether the Arctoidea is really a natural group. When, indeed, we go back to the Upper Eocene or Lower Oligocene, where this suborder is first definitely known, we find that Bears pass imperceptibly into Dogs, Dogs into Civets, Civets into Hyænas and Cats, while Weasels appear to be related to the Civets; and the principles adopted in the classification of recent forms consequently fail to enable us to make any really satisfactory arrangement.

Family Mustelidæ.—This family comprises the Sea-Otters, Otters, Badgers, and Weasels. In all existing forms the skull has no alisphenoid canal; there is never more than one upper true molar, and the lower true molars are nearly always two, although reduced to one in *Mellivora*. The upper true molar has its inner tubercular portion wider than the outer or cutting moiety (fig. 1306), this feature being most developed in the Otters (fig. 1303); and the



Fig. 1303.—Palate of *Lutra cinerea*; India.

cusps of the blade of the lower carnassial are comparatively low (fig. 1308). The palate is comparatively wide, and the premolars are somewhat crowded together; while the auditory bulla has no septum, and is usually, but slightly, inflated. It is suggested by Dr Scott that the *Mustelidæ* are a branch from the primitive *Viverridæ*, and there is considerable evidence in favour of this view, which, if true, at once breaks up the Arctoidea.

The existing *Lutrine* section may be palæontologically divided into *Lutra* and *Enhydra*; the latter being a marine form unknown

in a fossil state. The species of *Lutra* are characterised by the great constriction of the skull in the orbital region, and usually by the more or less squared contour of the crown of the upper true molar, and the great development of the inner tubercle of the last upper premolar, which forms a crescentoid ridge; both these features being well shown in fig. 1303. In the typical *L. vulgaris* the dental formula is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{3}$, $M.\frac{1}{2}$, but in some existing species the first upper premolar may be absent (fig. 1303), and other variations occur in fossil forms. This genus may be divided into three groups, which it is quite permissible to regard as distinct genera, and of which the first and third are extinct. The *Enhydriodont*, or most specialised group, comprises two large otters respectively from the Pliocene Siwaliks of India and the Middle Miocene of Italy, which attained dimensions fully equal to those of the existing *L. brasiliensis*. In both these forms the first upper premolar is absent, and in the Indian *L. sivalensis* the second premolar may likewise disappear. In this species, moreover, the fourth upper premolar or carnassial (fig. 1305) differs from that of all other otters in that the inner crescent consists of three distinct tubercles; but the Italian *L. Campanii* (fig. 1304) connects in this respect the Indian species with the true otters. The typical group, which includes all the existing forms, is known to date from the Middle Miocene of Europe, and also occurs in the Tertiaries of America and the Indian Siwaliks. Remains of the existing *L. vulgaris* occur in the Norfolk Forest-bed; while the Siwalik *L. palæindica* is closely allied in the structure of its teeth and skull to the living hairy-nosed otter (*L. sumatrana*) of Asia. Finally, the *Lutrictine* group is represented only by *L. Valetoni*, of the Lower Miocene of the Continent, which is distinguished from all other Mustelines by the presence of a minute second upper true molar. This species is also characterised by the narrowness of the first upper true molar, and by the circumstance that the anterior upper premolars are placed immediately behind the canine, instead of being squeezed towards its inner side, as in fig. 1303. If regarded as generically distinct, this form should be known as *Potamotherium*. The Miocene *Trochictis* appears to connect the Otters with the Weasels.



Fig. 1304.—The right upper carnassial of *Lutra Campanii*; from the Miocene of Italy. In its natural position the outer ridge would be oblique, as in fig. 1303.

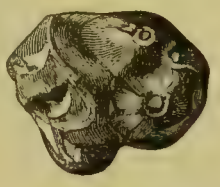


Fig. 1305.—The left upper carnassial of *Lutra sivalensis*; from the Pliocene of India. The outer ridge is broken.

Among the Badgers and their allies extinct species of the type

genus *Meles* occur in the Pliocene of Persia, the common Badger (*M. taxus*) being found in the Pleistocene of Europe; while extinct species of *Mellivora*, or Ratel (fig. 1306), have been described from the Pliocene of India, this genus being confined to that country

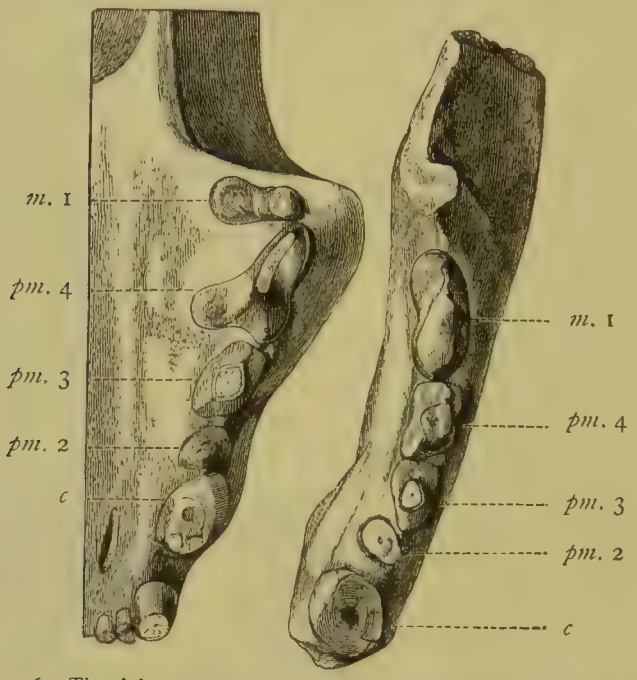


Fig. 1306.—The right upper and left lower dentition of *Mellivora sivalensis*; from the Pliocene of India.

and Africa. The last-named deposits also yield the extinct *Mellivorodon*. Species of the American genus *Mephitis* (*Conepatus*) occur in the Pleistocene cave-deposits of Brazil; while *Promephitis*, of the Pliocene of Greece, is considered to be allied. *Palæomephitis*, of the Miocene of Bavaria, which has been placed in this family, appears to be identical with *Viverra*.

The Weasels, or typical representatives of the family, which are divided into the existing genera *Mustela* (including *Putorius*), *Gulo*, and *Galictis*, occur commonly throughout the higher Tertiaries. *Mustela* (fig. 1307), in which the premolars vary from $\frac{3}{3}$ to $\frac{4}{4}$, and the inner cusp of the lower carnassial is frequently absent, is represented by numerous existing species in the Pleistocene of Europe, and by a number of extinct forms, some of which it has been proposed to separate under the names of *Plesiogale* and *Palæogale*, ranging down to the Quercy Phosphorites. A large species (fig. 1308) occurs in the Siwaliks of India, which was probably closely allied to *M. flavigula* of the same regions; and other large forms are

found in the Miocene of Bavaria, and the Pliocene of Greece and Persia; while the genus is also represented by a smaller species in the Pliocene of North America. *M. Larteti* of the Miocene of Sansan should perhaps be referred to the African genus *Ictonyx*.



Fig. 1307.—Right lateral view of the skull of the Polecat (*Mustela putorius*).

The extinct *Plesictis* occurs in the Lower Miocene and Upper Eocene (Oligocene) of Europe, and is characterised by the presence of $\frac{4}{4}$ premolars, and the circumstance that the temporal ridges of the cranium do not unite to form a sagittal crest, as they do in *Mustela*. The inner portion of the upper true molar, as in some of the Miocene species of *Mustela* (*Palæogale*), becomes narrower than the outer, and the auditory bulla is more inflated; both these features indicating affinity with the Viverrine genus *Stenoplesictis*. The existing genus *Galictis* of America is represented in the Pleistocene of the two divisions of that Continent; while the Arctic *Gulo* occurs in the Pleistocene of Europe, where remains of the existing Wolverine (*G. luscus*) are met with.



Fig. 1308.—Upper and outer view of the left lower carnassial of *Mustela*; from the Pliocene of India.

Family Procyonidæ.—The *Procyonidæ* may be taken to include both the American Racoons and Coatis and the Indian *Ælurus*, but are of small palæontological importance. In all living genera the true molars are $\frac{2}{2}$ in number; and the American forms have no alisphenoid canal. *Nasua* (Coati) occurs fossil in the Pleistocene of Brazil; and the extinct *Cynonasua*, characterised by the presence of three lower true molars, is found in the older *infra*-Pampean of Patagonia. *Procyon* (Racoon) is represented in the Pleistocene of North America; while *Leptarctus* from the same deposits, and *Arctodus* from the Pleistocene of South Carolina, are extinct genera

connecting the present family with the next. *Ælurus* is represented at the present day by a single species from Nipal and the adjacent regions. In common with the American members of the family it is characterised by the second lower true molar being longer than the first, and by the absence of a "carnassial" character in the latter. The molars are, however, of an unusually complex character; and the last one of the lower jaw presents a decided approximation to the third molar of certain Ungulates. The only fossil that has been referred to this genus is a fragment of a mandible with the last true molar from the Red Crag of Suffolk. It is, however, advisable to await further information before admitting this determination as certain.

Family Ursidæ.—Palæontologically it appears advisable to include in this family not only the Bears, but also the Dogs (*Canidæ*), since the passage from one type to the other is so complete as to render it impossible to draw any satisfactory distinction between them. Although no precise definition of this family can be given, the following points may be noticed. With the exception of the

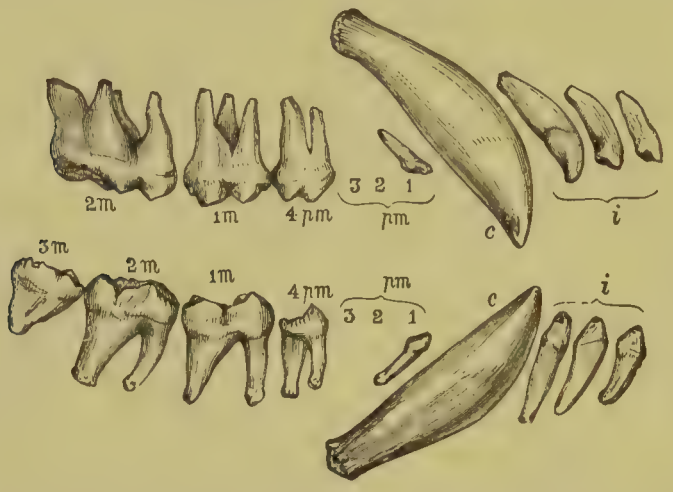


Fig. 1309.—Outer view of the right dentition of the Polar Bear (*Ursus maritimus*). Reduced. *i*, Incisors; *c*, Canine; *pm*, Premolars; *m*, True molars.

existing genus *Æluropus* the skull has an alisphenoid canal. The upper true molars are frequently two in number, but they may be reduced to one (*Icticyon*), or increased to three (*Amphicyon*) or four (*Otocyon*); while the corresponding teeth of the lower jaw are nearly always three in number, although they may be reduced to two, and in *Otocyon* are augmented to four. The first upper true molar is invariably placed behind the carnassial, and the latter generally has two lobes. The upper true molars may have either oblong (*Ursus*), squared (*Hyænarctus*), or triangular crowns; and the talon of the

lower carnassial is well developed. The auditory region may either have a depressed bulla, without an inner septum (*Ursus*), as in the existing *Mustelidæ*, or (*Canis*) may have an inflated bulla with an incomplete septum approximating to that of the *Viverridæ*. The least

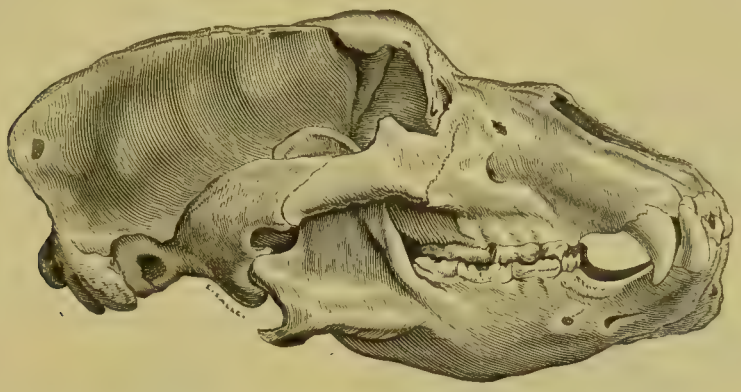


Fig. 1310.—Right lateral aspect of the skull of the Cave-Bear (*Ursus spelæus*); from the Pleistocene of Germany. Reduced.

specialised forms have an entepicondylar foramen to the humerus, and a third trochanter to the femur. The feet are digitigrade in *Canis* and plantigrade in *Ursus*. In common with the majority of the Carnivora Vera, and also many of the Creodonta, the second lower incisor is thrust up above the line of the first and third.

In the type genus *Ursus* the dental formula is usually *I.* $\frac{3}{3}$, *C.* $\frac{1}{1}$, *Pm.* $\frac{4}{4}$, *M.* $\frac{2}{3}$, but in *U.* (*Melursus*) *labiatus* the number of the incisors is reduced to $\frac{2}{3}$. The second and third premolars are usually shed at an early age; the upper carnassial (*pm.* 4, fig. 1309) is shorter than the first true molar, and lacks the marked sectorial character which it presents in most other Carnivora; and the upper true molars are greatly elongated, and have flat tuberculated crowns. The foramen has disappeared from the humerus; and the olecranon of the ulna (fig. 1311) has become very short; while the femur has no third trochanter. This genus may be regarded as in some respects very specialised, although retaining generalised features in its plantigrade and pentedactylate feet. It is of com-

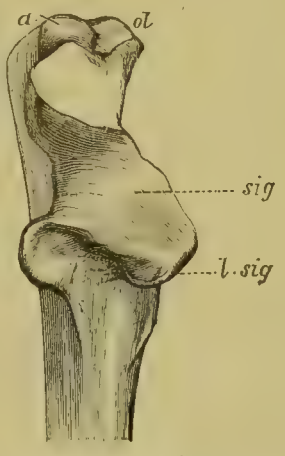


Fig. 1311.—Anterior aspect of the proximal extremity of the right ulna of *Ursus arctus*. One-half natural size. Letters as in fig. 1300.

paratively modern origin; the earliest known species being *U. Theobaldi*, of the Pliocene of India, which was the ancestor of the existing *U. labiatus* of the same country. The last-named species is found in a fossil state in the caves of Madras. In the Upper Pliocene of Europe we have the small *U. etruscus;* and in the Pleistocene of the same area the existing European Brown Bear (*U. arctus*), the allied or identical North American Grizzly (*U. horribilis*), and the huge extinct *U. spelæus*, or Cave-Bear (fig. 1310). The latter species is characterised by the prominent ridge above the orbits, and the extremely fine tuberculation of its molars; its remains are found in extraordinary abundance in the bone-caves

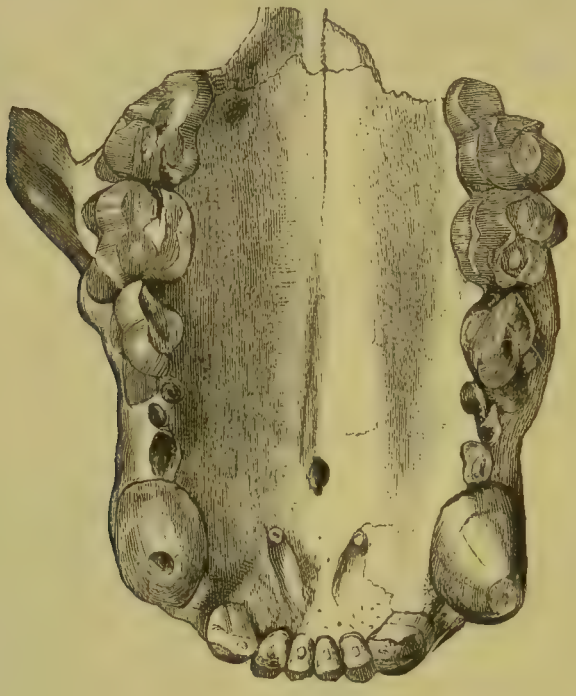


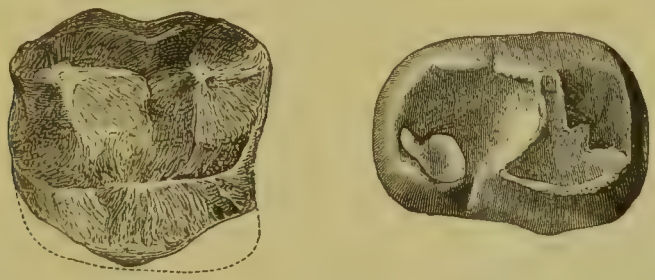
Fig. 1312.—Palate of *Arctotherium bonariense;* from the Pleistocene of South America. One-fourth natural size.

of the Continent. Very noteworthy is the occurrence of abundant remains of Bears in the caverns of North Africa, since but one living species is found in the whole of that vast continent. In the Pleistocene of South America and California we meet with the huge *Arctotherium* (fig. 1312), in which the upper carnassial is relatively longer than in *Ursus*, while the crowns of the true molars are more nearly square; so that its dentition serves to connect that of *Ursus* with that of the next genus. According to Professor Cope the humerus has a foramen. The genus *Hyænarctus* occurs first in the Middle Miocene of Europe, where the species are of small size

(fig. 1313), and is represented by much larger forms in the Pliocene of India, China, and Europe. In this genus the proximal extremity of the ulna (fig. 1300) has an elongated olecranon similar to that of *Amphicyon* and *Canis*. There is also a third lobe to the upper carnassial (whereby it resembles the corresponding tooth of *Hyæna*), while the first upper true molar is square (fig. 1314) in one species, and imperfectly triangular in another; the lower carnassial resembling that of *Canis*. The small *H. anthracitis* of the Middle Miocene of Italy may be identical with *H. minutus*. Before noticing the forms connecting *Hyænarctus* with *Canis*, we must mention some extinct genera more or less nearly allied to the present group, and which Dr Schlosser also regards as related to the *Procyonidæ*. Among these are *Simocyon* (*Pseudocyon* or *Metarctus*) of the Pliocene of Greece and Hungary, in which the number of the cheek-teeth is $Pm.\ \frac{2}{(2-4)}$, $M.\ \frac{2}{2}$; and *Enhydrocyon* (fig. 1315), of the Miocene of North America, in which the cheek-teeth number $Pm.\ \frac{3}{3}$, $M.\ \frac{2}{2}$, the cranium is very short, and the lower carnassial has a cutting talon. *Oligobunis* of the Miocene, and *Tomarctus* of the Pliocene of the same country are also more or



Fig. 1313.—Outer and palatal aspects of the left upper true molars of *Hyænarctus minutus*; from the Middle Miocene of Silesia. (After Koken.)



A B

Fig. 1314.—First upper (A) and second lower right true molar (B) of *Hyænarctus*; from the Pliocene.

less nearly related types. Here we may also place *Hyænocyon* of the Miocene and *Ælurodon* (*Prohyæna*) of the Pliocene of North America, though Dr Schlosser, on wholly insufficient grounds, would refer both to the *Hyænidæ*. The former has the molars

reduced to $\frac{1}{1}$; while in the latter the upper carnassial has three lobes like *Hyænarctus*, the number of teeth according to Professor Cope being the same as in *Canis*, and the humerus having no foramen. More nearly allied to the *Hyænarctus* group is *Cephalogale*,

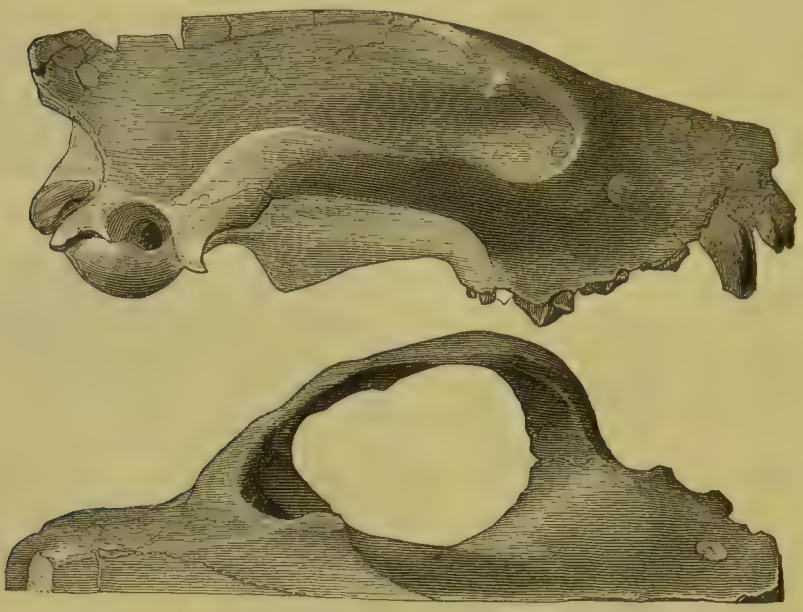


Fig. 1315.—Lateral and upper view of one-half of the cranium of *Enhydrocyon stenocephalus*; from the Miocene of North America. One-half natural size. (After Cope.)

in which the two upper true molars (fig. 1316) become more or less triangular, but the carnassial in both jaws (figs. 1316, 1317) is comparatively short, with low cusps. This genus, according to Dr Schlosser's emendation, is comparatively abundant in the Upper Eocene and Lower Miocene of the Continent; many of the species having been included by Dr Filhol in *Cynodictis*. Extremely near to those species of *Hyænarctus* in which the upper true molars are triangular is the gigantic *Dinocyon* from the Middle Miocene of Europe, in which the above-mentioned teeth become perfectly triangular like those of *Canis*; and we may here mention *Brachycyon* from the Upper Eocene of France. The widely-spread genus *Amphicyon* (in which *Pseudamphicyon* of Dr Schlosser may be in part included) occurs in Europe from the Upper Eocene to the



Fig. 1316.—The last four left upper teeth of *Cephalogale Gryei*; from the Upper Eocene of France.

Middle Miocene of Europe, and is also found in the Pliocene of India; the forms from the Upper Eocene of North America which have been referred to it, are regarded by Dr Scott as distinct, and have been named *Daphænus*. Its teeth closely resemble those of *Canis*, but there are three upper true molars; the femur has, however, a third trochanter, the feet are plantigrade and pentedactylate, the distal end of the humerus has a foramen, and the auditory bulla is somewhat inflated, with either a very rudimentary or no septum.[1] This genus has therefore the dentition of a Dog, coupled with limbs more like those of a Bear; and it is a curious comment on the attempt to maintain the families *Canidæ* and *Ursidæ* that while Professor Flower places *Amphicyon* in the former, Dr Schlosser refers it to the latter. This genus is evidently a very



Fig. 1317.—Right ramus of the mandible of *Cephalogale brevirostris*; from the Upper Eocene of France.

generalised form, from which many others may have been derived. In *Canis*, comprising the Dogs, Wolves, and Foxes, the dental formula is normally $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{4}$, $M.\frac{2}{3}$, but in some forms (*Cyon*) the lower true molars may be reduced to two, and in others (*Lycorus*) there are but three lower premolars, while occasionally the third upper true molar is retained. The characteristic features of the teeth are shown in figs. 1302 and 1318; but it may be observed that the relative length of the carnassial and the degree of obliquity of the cusp-line in the lower carnassial varies in different species; the most specialised forms showing the greatest development of these features. The third lower premolar has a hinder basal cusp which is usually wanting in *Amphicyon*; the humerus has no foramen; the femur has lost the third trochanter; the feet are digiti-

[1] The general characters of the base of the skull of *Amphicyon* are Canoid, but in the presence of postparietal and mastoid foramina it agrees with the Bears.

grade; and the hallux is wanting in the pes. This genus probably commenced in the Upper Miocene of Œningen, and is widely distributed over all the world from the Pliocene upwards. The Wolf (*C. lupus*) ranges down to the European Pleistocene, and the allied *C. Cautleyi* is found in the Pliocene of the Siwalik Hills. *C. curvi-*



Fig. 1318.—Palatal aspect of right lower and upper dentition of *Canis argentatus*. The oblique line in the lower carnassial is the cusp-line. (After Huxley.)

palatus of the latter deposits shows signs of affinity with the African *Otocyon* (Fennec). *Lycaon*, now confined to Africa, and distinguished by having an anterior cusp to the last lower premolar, is found in the Pleistocene of Glamorganshire. *Palæocyon*, of the Brazilian Pleistocene, is regarded by Dr Schlosser as indistinguishable from *Canis*. *Temnocyon*, of the North American Miocene, has the talon of the lower carnassial secant, and a foramen to the hume-

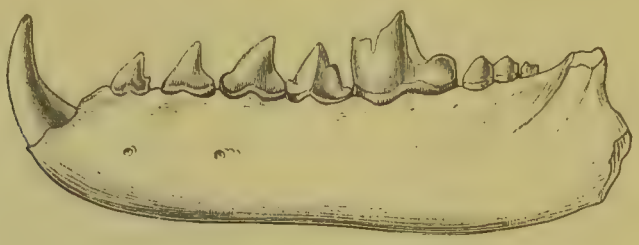


Fig. 1319.—Left ramus of the mandible of *Cynodictis lacustris*; from the Upper Eocene of France. (After Gaudry.)

rus; while in the existing American *Icticyon* (*Speothos*), which is represented in the Brazilian Pleistocene, the lower carnassial has not only a secant talon but also lacks the inner cusp. Perhaps, however, the most interesting genus of the whole group is *Cynodictis* (in which we may include *Cynodon*, *Amphicynodon*, and *Pachycyno-*

don), of the Upper Eocene and Lower Miocene of the Continent, and also of the White-river Miocene of North America, where it has been described as *Galecynus*. In this genus the dental formula is usually the same as in *Canis*, but in some cases (as in that genus) there are only two lower true molars. The teeth (figs. 1319, 1320) resemble also those of the *Viverridæ*, the carnassials being never very long, and the cusp-line of the lower one transverse; and the humerus has a foramen. The auditory bulla is inflated, but according to Dr Filhol, has no septum. This genus is, indeed,

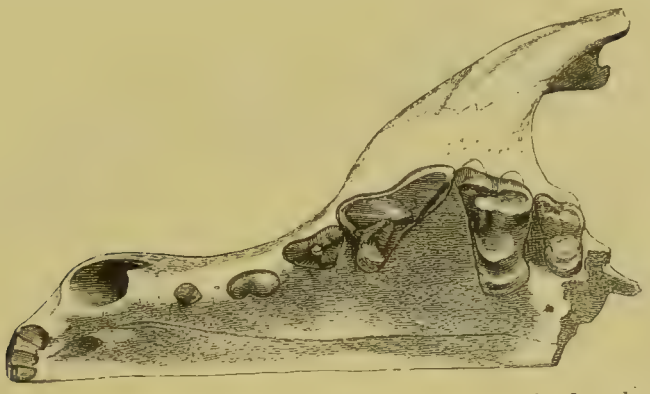


Fig. 1320.—Left half of the palate of *Cynodictis longirostris*; from the Upper Eocene of France.

one closely connecting the Canoids and Viverroids; and since it is pretty evident that the *Hyænidæ* and *Felidæ* are divergent branches from an early Viverroid stock it is probable that *Cynodictis* represents a type not far removed from the one which has given rise to several of the more specialised Carnivores, and is itself derived from *Amphicyon*, or an allied type.

Family Miacidæ.—This family is provisionally adopted to include the Eocene genera *Miacis* and *Didymictis*, which appear to be primitive forms allied to both Canoids and Viverroids, but which Professor Cope placed among the Creodonta. *Miacis* (= *Uintacyon* and *Viverravus*) occurs in the Upper, or Bridger, Eocene of North America, and according to Dr Schlosser, who places it with the Canoids, in both the Lower and Upper Eocene of France. *Didymictis* (*Limnocyon*), which occurs in the Puerco, Wasatch, and Bridger Eocenes of North America, is included by Dr Schlosser in the *Viverridæ*. *Dromocyon* is noticed on page 1453.

Family Viverridæ.—The Viverroids are comparatively small Carnivores, showing such close affinities in one direction with *Cynodictis* among the *Ursidæ*, in another with the *Mustelidæ*, and in a third with the *Hyænidæ* and the *Felidæ*, that their accurate definition is quite impossible. The skull in existing forms generally

has an alisphenoid canal; and the auditory bulla is inflated and has a complete septum. There are usually two true molars in each jaw, although the second is wanting in *Prionodon*. Those of the upper jaw (fig. 1322) are usually triangular, and are always narrower internally than externally, although they may be narrow in *Viverra* (fig. 1322) and very broad in *Paradoxurus*; and, except in *Cryptoprocta* are placed behind the carnassial. The cusps of the lower carnassial are generally very tall; the premolars are spaced; and the palate, like the entire skull, is long and narrow. The upper carnassial is subject to great variation in relative length. In typical forms the blade of the lower carnassial has an inner cusp, while its cusp-line is transverse, and the talon is relatively large. The humerus usually has an entepicondylar foramen. The feet are plantigrade, and usually have five complete digits; and their claws, as a rule, are comparatively straight and only slightly retractile, and are not protected by a bony sheath. Exclusive of *Miacis* and its allies, which are here regarded as representing a separate family, the *Viverridæ* are characteristic of the Old World. The Oriental genus *Paradoxurus*, characterised by its broad upper molars, is at present unknown in a fossil condition. The more widely spread *Herpestes* (Mongoose) is characterised by its narrow upper molars, by the presence of an inner tubercle to the third upper premolar, and of a hinder cusp to the fourth lower premolar. This genus is represented in a fossil state by remains of the existing *H. nipalensis* (fig. 1321) in the Pleistocene of India, and by extinct species in the Upper Eocene and Miocene of Europe. *Amphictis*, from the Lower Miocene (Upper Oligocene) of France, seems to be closely allied to *Viverra*, but the second lower true molar is longer and has two distinct roots. The type genus *Viverra* (fig. 1322), which has no inner tubercle to the third upper premolar, commences in the Upper Eocene of England and France (*V. Hastingsiæ* and *V. angustidens*), and occurs right through the succeeding Tertiaries till the Lower Pliocene of France, where it is represented by *V. Pepraxti*. The latter Civet, together with other allied species from the Pleistocene and Pliocene of India, presents, however, certain dental features in which it approximates to *Ictitherium*. The Oriental genus *Prionodon*, in which there is only one upper true molar, and the inner cusp of the lower carnassial is very small, while the humerus has a foramen, is not known to occur in a fossil state. So far as can be determined from the lower



Fig. 1321.—The right ramus of the mandible of *Herpestes nipalensis*; from the Pleistocene of Madras. All the teeth except the carnassial and the canine are wanting.

jaw, *Palæoprionodon*, of the Quercy Phosphorites, appears to be so closely allied to *Prionodon*, that it is somewhat difficult to see how it can be even generically separated. Closely allied to *Palæoprionodon* is *Stenoplesictis*, from the same deposits, in which the dental formula is $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{4}$, $M.\frac{2}{2}$, or the same as in *Viverra*. This genus presents, however, decided indications of affinity with



Fig. 1322.—Palatal aspect of the left upper dentition of the Zibeth (*Viverra zibetha*); from India.

the Musteloid *Plesictis*, on which account it is placed by Dr Schlosser, together with *Palæoprionodon*, in the same family; but its dentition and the contour of the skull are decidedly Viverrine, and, according to Dr Scott, the bulla has a complete septum, of which the position is visible externally, as in modern Viverrines. It is, however, quite probable that we may have in these generalised

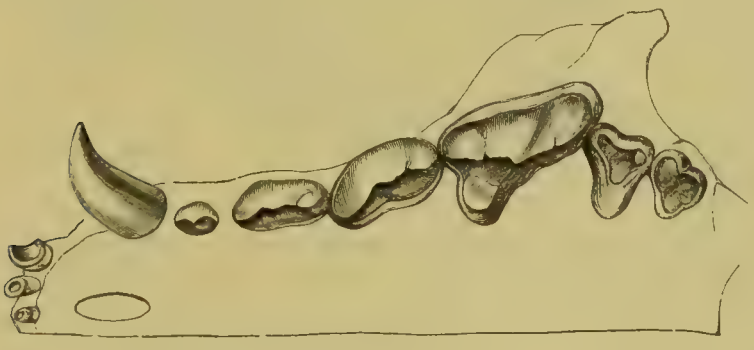


Fig. 1323.—Palatal aspect of the left upper dentition of *Ictitherium robustum*; from the Pliocene of Greece. (After Gaudry.)

forms the ancestral types of the *Mustelidæ*, which from this view will have lost the septum of the bulla independently of the Bears. In all the above-mentioned genera the upper carnassial has only two lobes, but in *Ictitherium* (*Thalassictis*) they are increased to three, as in *Hyæna*. *Ictitherium* occurs in the Lower Pliocene of Greece, Hungary, and France; and its upper true molars (fig. 1323) have

become relatively smaller than in *Viverra*, and in the figured species have a tendency to become placed on the inner side of the carnassial. The genus *Cryptoprocta*, which is unknown in a fossil state, approximates in the character of its dentition and its semi-retractile claws to the *Felidæ*.

Family Hyænidæ.—The above-mentioned genus *Ictitherium* may without much doubt be regarded as the ancestral type of the *Hyænidæ*, which form a family of comparatively recent origin and entirely confined to the Old World.[1] The transition to *Ictitherium* is indeed



Fig. 1324.—Oral view of the right half of the palate and right ramus of the mandible of the Spotted Hyæna (*H. crocuta*), together with outer view of the lower carnassial tooth. One-half natural size.

so close that it is impossible to give a distinctive diagnosis of the family. Usually, however, there is but a single upper true molar, which is of small proportionate size, and is generally placed more or less entirely on the inner side of the carnassial; the latter tooth (fig. 1325) always having three distinct lobes to the blade, and a well-developed inner tubercle. The lower carnassial, or first true molar (fig. 1324) has a very large blade, and the hind talon com-

[1] This is exclusive of *Ælurodon* (*Prohyæna*) and *Hyænocyon*, which Dr Schlosser transfers from the *Ursidæ* to this family.

paratively small; while its inner cusp, if present, is likewise relatively small. There is never more than one lower molar (*m.* 2) behind the carnassial, and if present that tooth is very small. In the existing genus the humerus has no entepicondylar foramen, while, at least in the living species, each foot has but four digits, of which the claws are non-retractile. The most generalised member of the family is the genus *Palhyæna*, of the Lower Pliocene of Greece, France, and Persia, which has been included by many writers in *Ictitherium*, but of which the carnassial teeth are essentially those of a Hyæna. The dental formula is *I.* $\frac{3}{3}$, *C.* $\frac{1}{1}$, *Pm.* $\frac{4}{4}$, *M.* $\frac{2}{2}$, or the same as in *Viverra*. The first upper true molar is placed entirely on the inner side of the large carnassial; the lower carnassial, except for its rather larger talon, is almost indistinguishable from that of the Striped Hyæna, while the second lower true molar is comparatively small. The first lower premolar is very minute, and in their compressed crowns the other premolars are more like those of *Viverra* than those of existing Hyænas. The type species is comparatively small, with slender jaws, and the muzzle is elongated after the Viverroid fashion. The imperfectly known *Lepthyæna*, of the Indian Siwaliks, is closely allied to, if not identical with, the preceding genus. The remaining forms may be included in the genus *Hyæna*, which may be divided into groups corresponding to the genera of some writers, although there is an almost complete transition from one to the other. In all cases there is never more than a single upper true molar, while in existing forms the normal dental formula is *I.* $\frac{3}{3}$, *C.* $\frac{1}{1}$, *Pm.* $\frac{4}{3}$, *M.* $\frac{1}{1}$. In some fossil forms, however, the first upper premolar may be absent, while in others there may be a small first lower premolar or a second lower true molar.

Of the more generalised forms classed in the *Lychyænine* group (*Lychyæna*), as represented by *H. macrostoma* of the Pliocene of India, and *H. chæretis* of that of Greece and Samos, the muzzle is long, the premolars, of which there are four in the lower jaw, are compressed, the first upper true molar is placed partially behind the carnassial, the lower carnassial has an inner cusp, and there was probably a second lower true molar. In the *Hyænictine* group (*Hyænictis*), which likewise occurs in the Pliocene of India and Europe, the second lower true molar is still retained as a very minute tooth, but the premolars are more like those of existing forms, and the comparatively large *m.* 1 is placed entirely on the inner side of the carnassial. The muzzle is also comparatively short. In the Indian *H. sivalensis* the first lower premolar is lost, although retained in the European *H. chæretis*. This group forms, indeed, a complete

connection between *Palhyæna* and the next group. In the typical or *Euhyænine* group, as represented by the living Indian Striped Hyæna (*H. striata*) the premolars form blunt cones admirably adapted for crushing large bones. In this group the upper carnassial (fig. 1325) has a short third lobe, while the corresponding



Fig. 1325.—The right upper carnassial tooth of *Hyæna striata*, from the outer (A) and oral (B) aspects; from the Suffolk Crag.

lower tooth still retains its inner cusp and distinct hind talon; but the first lower premolar and second true molar have totally disappeared. Remains referred to the existing species occur in the Suffolk Crag, the caverns of France and the Upper Pliocene or Pleistocene of Italy. *H. arvernensis*, of the Upper Pliocene of

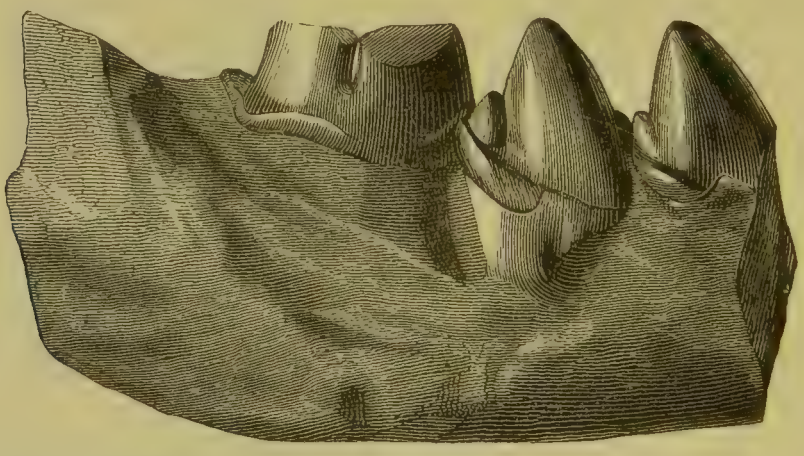


Fig. 1326.—Outer view of hinder part of the right ramus of the mandible of *Hyæna Colvini*; from the Pliocene of India.

France and Italy, seems to be allied to *H. brunnea* of the Cape; while *H. Perrieri* (*topariensis*), of the same deposits makes another step towards *H. crocuta*, having lost the inner cusp to $\underline{m.}$ 1. The most specialised or *Crocutine* group (*Crocuta*) is now represented by the Spotted Hyæna, and is characterised by the long third lobe of

the upper carnassial (fig. 1327, A), and by the loss of the inner cusp and reduction in the size of the hind talon of the lower carnassial (fig. 1327, B).

The most generalised representative of this group is *H. eximia*, of the Lower Pliocene of Greece and Persia, in which the first lower premolar is retained, but the second lower true molar is lost, as in all the other members of this group.[1] *H. Colvini* (fig. 1326) of the

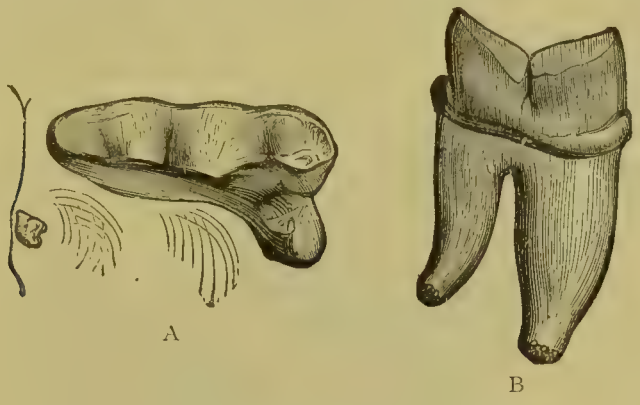


Fig. 1327.—(A), Palatal view of right upper carnassial and true molar; and (B), Outer view of right lower carnassial of *Hyæna crocuta*.

Indian Siwaliks, in which *pm.* 1 has disappeared, may probably be regarded as the ancestor of the existing Spotted Hyæna (*H. crocuta*); while *H. robusta*, of the Upper Pliocene of Italy, is allied to *H. Colvini*, but retains *pm.* 1.

The Spotted Hyæna is now found in South Africa, but occurs in a fossil state in the Pleistocene of both Europe and India. It is characterised by the minute size of the upper true molar (fig. 1327), and the extremely small size of the hind talon of the lower carnassial (*ibid.*) The facial part of the cranium (fig. 1328) is very broad and short.

Remains of the Spotted Hyæna occur in vast quantities in many European cave-deposits; and were especially abundant in the celebrated Kirkdale cave in Yorkshire, explored in the early part of this century by Dean Buckland, and also that of Gailenreuth in Franconia. That these caves were dens in which the Hyænas dwelt is evident from the marks of their teeth on the bones of other animals dragged in by them for food, as well as by other unmistakable evidence.

Family Felidæ.—The *Felidæ*, in which the *Nimravidæ* of Professor Cope are included, are the most specialised representatives of the entire order; this being especially shown in the existing forms by the shortness of the skull, in which there is no alisphenoidal

[1] In a skull of the Spotted Hyæna in the College of Surgeons there is a second lower true molar on one side.

canal, the reduction in the number of the cheek-teeth, the great development of the canines and carnassials, and the digitigrade feet, with their strongly curved and generally perfectly retractile claws, protected by complete bony sheaths. The auditory bulla is greatly inflated, and completely divided by a vertical bony septum. The dental characters common to the entire family are the strong development of the canines, the presence of not more than one upper and two lower true molars, and the circumstance that the three lower incisors are placed in the same horizontal line. With one exception all the known forms have an entepicondylar foramen to

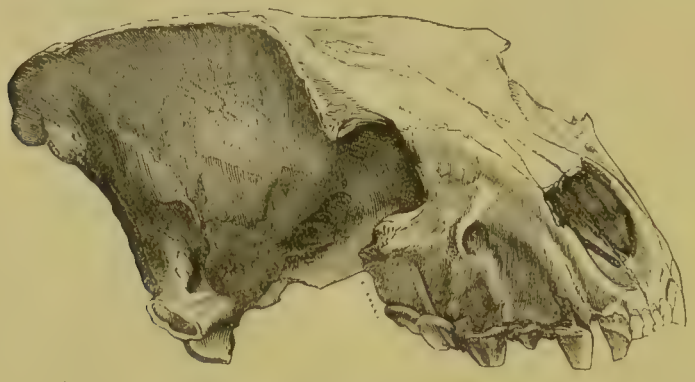


Fig. 1328.—Oblique lateral view of the cranium of *Hyæna crocuta;* from the German Cave. Reduced. (After Owen.)

the humerus. This family was probably derived from the ancestors of the modern *Viverridæ*, the view taken by Dr Schlosser that the true *Felidæ* are directly descended from the Creodonts being very improbable. The earlier forms, constituting the *Nimravidæ* of Professor Cope, present generalised features which are lost in the true Cats.

Here may be mentioned the remarkable genus *Proælurus* from the Lower Miocene and Upper Eocene of France, which includes small Carnivores of generalised affinities, which have been placed by Professor Cope in the true *Felidæ* and by Dr Schlosser in the *Mustelidæ*. The skull agrees with that of *Cryptoprocta* in the possession of an alisphenoidal canal, and the teeth also present resemblances to those of that genus, the formula of the cheek-teeth being *Pm.* $\frac{4}{4}$, *M.* $\frac{1}{2}$. The femur has a third trochanter, and the phalangeals, according to Messrs Scott and Osborn, resemble those of *Dinictis*. This genus also shows signs of affinity with *Palæoprionodon* and *Pseudælurus*.

Dinictis is a somewhat larger but likewise very generalised form, from the Miocene of the United States, which was at one time

classed by Dr Scott with *Cryptoprocta* in a separate family, but is now placed by him in the *Nimravidæ*. The formula of the cheek-teeth is *Pm.* $\frac{3}{3}$, *M.* $\frac{1}{2}$; the upper carnassial has no anterior lobe; the alisphenoid canal is retained; the femur has a third trochanter; the astragalus is flattened and articulates with the cuboid; and the terminal phalangeals, although retractile, are not protected by bony sheaths. Generalised features are also displayed in the base of the skull; and the bones of the skeleton approximate to those of *Cynodictis* and other primitive types.

Of the other generalised forms which may perhaps be included in this family we may mention *Æluropsis* of the Pliocene of the Siwalik Hills, and *Pseudælurus* typically from the Middle Miocene, but recorded by Dr Filhol from the Upper Eocene Phosphorites of France. *Æluropsis* is very imperfectly known, but its mandible seems to approach that of the Machærodonts. Dr Schlosser would include in this genus some of the forms from the French Phosphorites referred

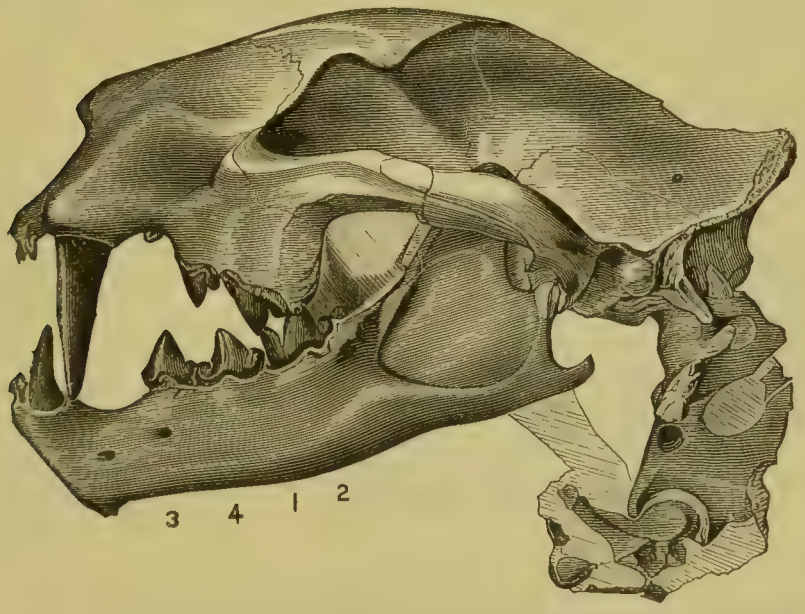


Fig. 1329.—Left lateral aspect of the skull and anterior cervical vertebræ of *Nimravus gomphodus*; from the Miocene of North America. Two-fifths natural size. 3, 4, Premolars; 1, 2, True molars. (After Cope.)

by Dr Filhol to *Proælurus*, and would change the name to *Haplogale*, and place it in the *Mustelidæ*. The typical *Pseudælurus* has three lower premolars, and no inner cusp to the lower carnassial; but in *P. intermedius*, which Dr Schlosser makes the type of the genus *Stenogale*, there were four lower premolars in some instances,

and the lower carnassial retained a small inner cusp. Turning to the consideration of fossil forms which may undoubtedly be included in the present family in the sense in which it is here employed, we find that they have a larger number of teeth than existing forms, and many or all of them retain the alisphenoidal canal. Of these *Æluractis* (*Ælurogale*) is typically represented by a large species in the Quercy Phosphorites of France, and has also been recorded from the Pliocene of India. The formula of the cheek-teeth is *Pm.* $\frac{3}{(3-4)}$, *M.* $\frac{1}{(1-2)}$; but it is not improbable that this genus may prove inseparable from *Nimravus* (fig. 1329), in which the number of lower premolars is reduced to two. Other allied genera from the North American Miocene are *Archælurus*, with *Pm.* $\frac{3}{(3-4)}$, *M.* $\frac{1}{2}$; *Pogonodon* (fig. 1330), with *Pm.* $\frac{3}{3}$, *M.* $\frac{1}{1}$; and *Hoplophoneus*, with *Pm.* $\frac{(2-3)}{2}$, *M.* $\frac{1}{1}$. In addition to the generally large number of premolars, and the presence of a second lower true molar, this group

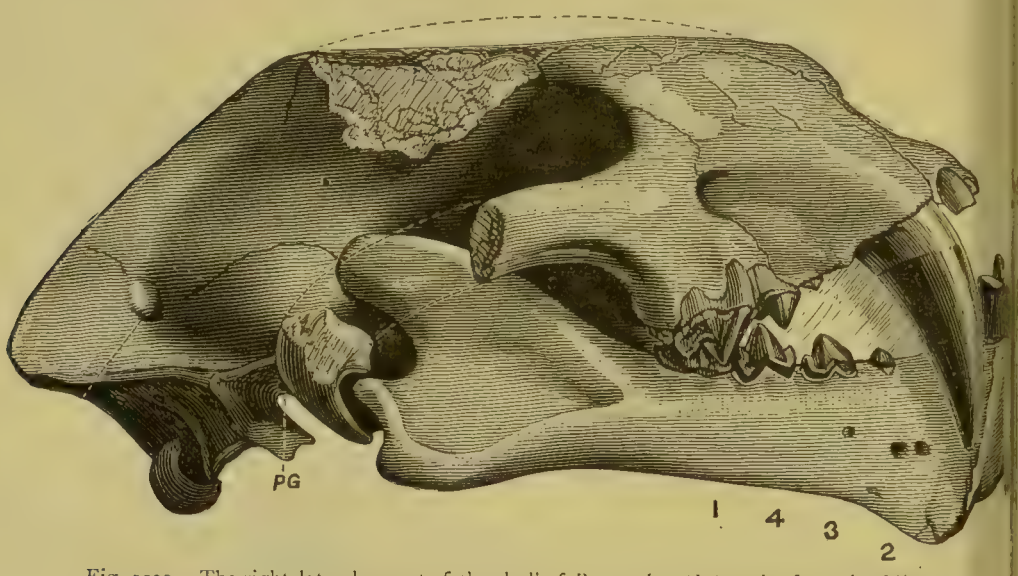


Fig. 1330.—The right lateral aspect of the skull of *Pogonodon platycopis;* from the Miocene of North America. About two-fifths natural size. 2, 3, 4, Premolars; 1, True molar; *PG*, Postglenoid process. (After Cope.)

exhibits the Viverroid feature of a talon, and sometimes an inner cusp (*Hoplophoneus*), to the lower carnassial, and the general absence of the first lobe in the corresponding upper tooth (fig. 1329). In several of the genera the front of the mandibular symphysis is angulated and furnished with a descending flange, as in fig. 1330. In *Hoplophoneus*, of which the entire skeleton has been described by

Messrs Scott and Osborn, the hallux was well developed, there is a distinct line in the scapholunar indicating the boundaries of the scaphoid and lunar, and the femur has a third trochanter; the two last-named features being regarded by the above-mentioned authorities as inherited from a Creodont ancestor.

Turning to the true Cats we have, among existing forms, the Hunting-Leopard of India, forming the genus *Cynælurus*, which is distinguished by its non-retractile claws: it may be represented in the Pliocene of India. All the other "Cats" may be included in the genus *Felis*, although some writers have proposed to split it up into several genera. This genus is spread over the temperate and tropical regions of the greater part of the globe. Although there are five digits in the manus, the hallux of the pes is reduced to a rudiment of its metatarsal; the scapholunar has lost all trace of its primitive duality; and the third trochanter has likewise disappeared from the femur. The dental formula is usually $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{3}{2}$, $M.\frac{1}{1}$; but in some instances there are only two upper premolars, and occasionally there are three lower premolars as an abnormality. The upper carnassial (p^3, fig. 1331) has three

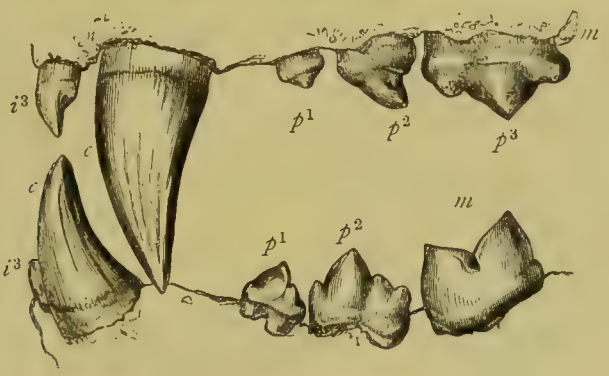


Fig. 1331.—Left lateral view of the dentition of the Lion (*Felis leo*). Reduced. i^3, 3d Incisor; *c*, Canines; p^1-p^3, 2d, 3d, and 4th upper premolars; *m*, True molars; p_1, p_2, 3d and 4th lower premolars.

lobes and a small inner tubercle; while the corresponding lower tooth (*ibid.*, *m*) has no inner cusp or hind talon, although the latter is represented by a minute tubercle in the Lynxes. In Europe this genus makes its first appearance in the Middle Miocene of France, and in North America in the Upper Miocene or Lower Pliocene Loup-Fork beds.

In the Pleistocene of Europe we meet with remains which cannot be distinguished specifically from the existing Lion, although the fossil form has been named *F. spelæa*. Remains of the Leopard (*F. pardus*) also

occur in the Continental cave-deposits; while in the corresponding deposits of Gibraltar we meet with the Pardine Lynx (*F. pardina*); and in those of Bengal we find remains of the Jaguar (*F. onca*) and Ocelot (*F. pardalis*), which now inhabit the same regions. In the Pliocene Siwaliks

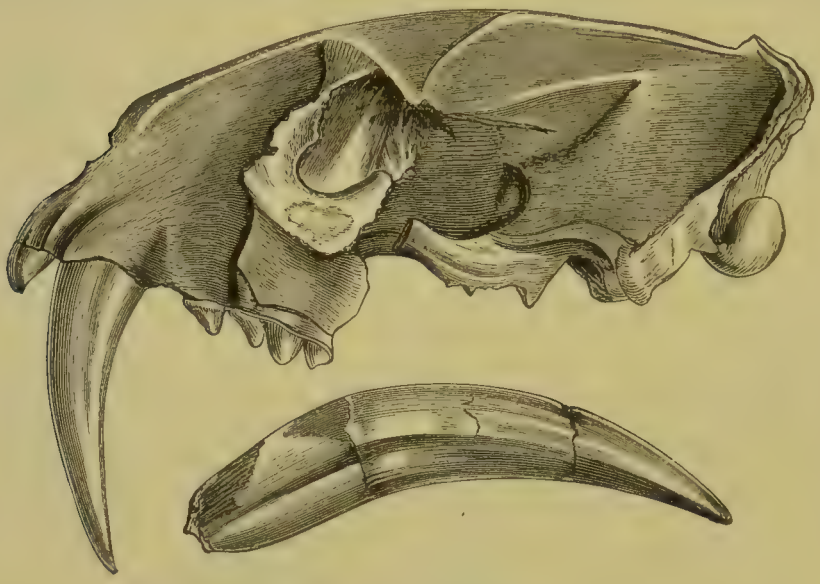


Fig. 1332.—Left lateral view of cranium (A), and larger view of an upper canine (B) of *Machærodus meganthereum;* from the Upper Pliocene of France. Reduced.

of India we meet with the huge *F. cristata*, which shows characters connecting it both with the Tiger and the Jaguar; and also smaller forms, one of which appears to have been closely allied to the existing *F. bengalensis*. In the Pliocene of North America large Cats were represented

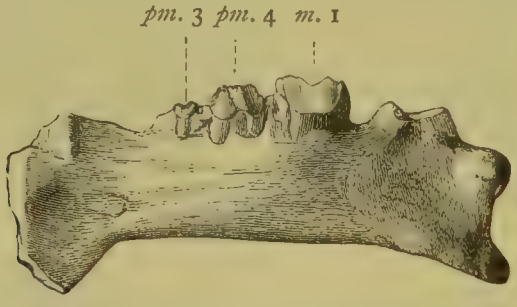


Fig. 1333.—Outer view of the left ramus of the mandible of *Machærodus sivalensis;* from the Pliocene of India. One-third natural size.

by *F. augusta* and *F. atrox*. In Europe, again, numerous species occur in the Pikermi beds of Greece; and we may also mention the comparatively small *F. arvernensis* and *F. issiodorensis*, of the French Pliocene, one of which probably also occurred in the corresponding deposits of Persia.

The most remarkable of the true Cats are, however, the extinct Machærodonts or Sabre-toothed Tigers, which are characterised by

the enormous development of the upper canines of the males, by the presence of a deep descending flange in the mandibular symphysis for the protection of the latter, and the angulation of the anterior extremity of this symphysis; the structure of the carnassial teeth being usually of the type of those of the existing Cats. In the type genus *Machærodus* (fig. 1332), which may be taken to include *Smilodon*, *Drepanodon*, and *Trucifelis*, there are three incisors in each jaw; the premolars in the upper jaw never exceed two, and there may be either two or only one of these teeth in the lower jaw; the latter variation occurring in different individuals of a single species. The upper carnassial (fig. 1334) is usually like that of *Felis*; but in the South American *M. neogæus* (fig. 1335) it has four distinct lobes, and is thus the most complex example of this type of tooth that is known. This genus ranges in time from the Quercy Phosphorites to the Pleistocene, and is found in America, Europe, Persia, and India. The South American *M. necator* stands alone among the *Felidæ* in having no foramen to the humerus. The last genus of the family is the curious *Eusmilus*, of the Quercy Phosphorites, in which there are only two incisors and one premolar in the mandible, and the descending flange of the symphysis of the latter is of enormous depth. The existence of this extremely specialised form at such an early epoch is noteworthy; not less so being the total extinction of the Machærodonts, which, it has been suggested, may be due to their excessive specialisation having rendered them incapable of obtaining their subsistence.

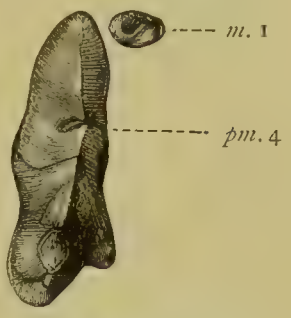


Fig. 1334.—Oral aspect of the left upper carnassial and true molar of *Machærodus sivalensis*; from the Pliocene of India.



Fig. 1335.—Right lateral view of the skull of *Machærodus neogæus*; from the Pleistocene of South America. Greatly reduced.

Suborder 3. Creodonta. — The members of the suborder Creodonta (or Carnivora Primigenia) are all extinct, and their serial position has led to much discussion. By some authorities they have been classed with the Polyprotodont Marsupials; from which, however, they differ by the presence of a complete milk-den-

tition, by the reduced number of incisors, and the absence of the inflection of the angle of the mandible, and of palatal vacuities. By others they have been regarded as closely allied to certain families of the Insectivora, and, together with the latter, are classed as a section of a large and ill-defined order termed the Bunotheria; while a third writer ranks them as an order of equal value with the existing Insectivora and Carnivora. Their relationship appears, however, on the whole, to be decidedly nearest to the true Carnivora, and they are accordingly here classed as a division of that order. They undoubtedly, however, exhibit affinities to the Insectivora, from which they are distinguished by the Carnivorous type of their incisors and canines; while the remarkable resemblance existing between their cheek-teeth and those of the Polyprotodont Marsupials is probably indicative of a distinct genetic relationship with that group. Mention has already been made of their resemblances to the Condylarthrous Ungulates.

The following are the chief characters of this suborder: The brain is of relatively small size; the fourth upper premolar and the first lower true molar are not differentiated as an opposed pair of carnassials, but resemble more or less closely the tooth immediately behind or in front of them, which is either conical or of a more or less secant type; and the upper true molars are either subtriangular or simply secant. The tibial face of the astragalus is, moreover, generally devoid of a groove; the scaphoid and lunar are usually separate; the femur has a third trochanter; and the feet were plantigrade. In all cases where there is the full number of incisors, the second pair in the lower jaw is thrust up above the other two, as in so many of the Carnivora Vera. The structure of the cranium approximates to that of *Amphicyon*.

Family Hyænodontidæ.—This family includes the most specialised forms. The dentition (fig. 1336) is of a markedly sectorial type, the inner tubercle of the hinder upper cheek-teeth being very small; and there is no inner cusp to the lower true molars. In the type genus the scaphoid and lunar of the carpus were united. *Hyænodon* has the dental formula $I.\ \frac{3}{3}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{4}{4}$, $M.\ \frac{2}{3}$; the inner tubercle of the two upper true molars is almost wanting, and the third lower true molar differs from the two teeth in front (fig. 1336), and somewhat resembles the carnassial of *Felis*. This genus includes species varying in size from a Leopard (*H. horridus*) to a small Fox (*H. vulpinus*), and is widely distributed both in time and space. Thus it is found in Europe, and also in North America, where it ranges from the Upper Eocene to the Lower Miocene; while in India it survived into the Pliocene. One species has been found in the Upper Eocene of Hampshire. The species from the

Upper Miocene of North America is remarkable as being the only known Mammal, except certain Edentates and Cetaceans, in which the pterygoids unite beneath the nasal passage. One of the European forms was originally described as *Taxotherium*. In the allied *Pterodon*, which, together with *Oxhyæna*, some writers refer to a distinct family, the third upper true molar is present, and has a

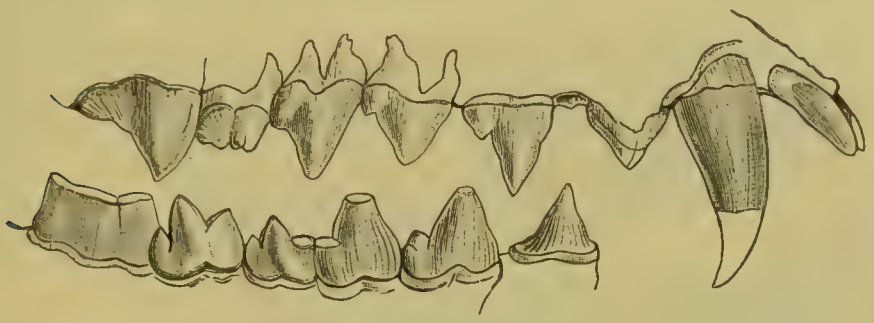


Fig. 1336.—Right lateral aspect of the dentition of *Hyænodon horridus*, wanting the teeth in advance of the second lower premolar; from the Miocene of North America. Reduced. (After Leidy.)

transversely elongated crown; there may be either two or three upper incisors, and the first lower premolar is sometimes absent. The first and second upper true molars differ from those of *Hyænodon* by the large size of their inner tubercle, and the last true molar is like the second; the cranium in many respects resembles that of *Amphicyon*. This genus is represented by

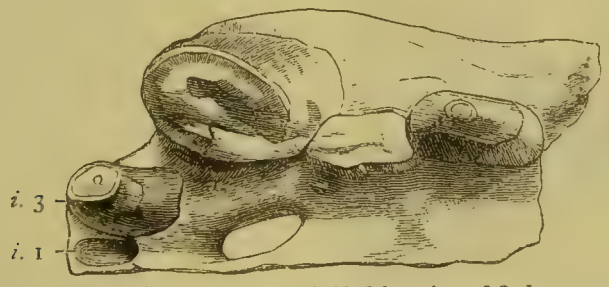


Fig. 1337.—The left side of the anterior half of the palate of *Oxhyæna galliæ*; from the French Phosphorites.

three comparatively large species from the Upper Eocene (Lower Oligocene) of Europe. An allied form, from the French Phosphorites, has been named *Pseudopterodon*, and connects the former genus with *Theuritherium*. The remarkable genus *Oxhyæna*, of the North American Eocene and the French Phosphorites, has an elongated mandibular symphysis, with the dental formula $I.\ \frac{(2-3)}{0}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{4}{4}$, $M.\ \frac{2}{2}$; the species figured in the woodcut having only

two upper incisors. *Protopsalis* is another Eocene American genus; while *Hemipsalodon*, from the White River Miocene of Canada, is the largest form yet known in the suborder, and has the full typical Eutherian dentition.

Family Proviverridæ.—The members of this family (fig. 1338) are characterised by the large size of the inner tubercle of the upper

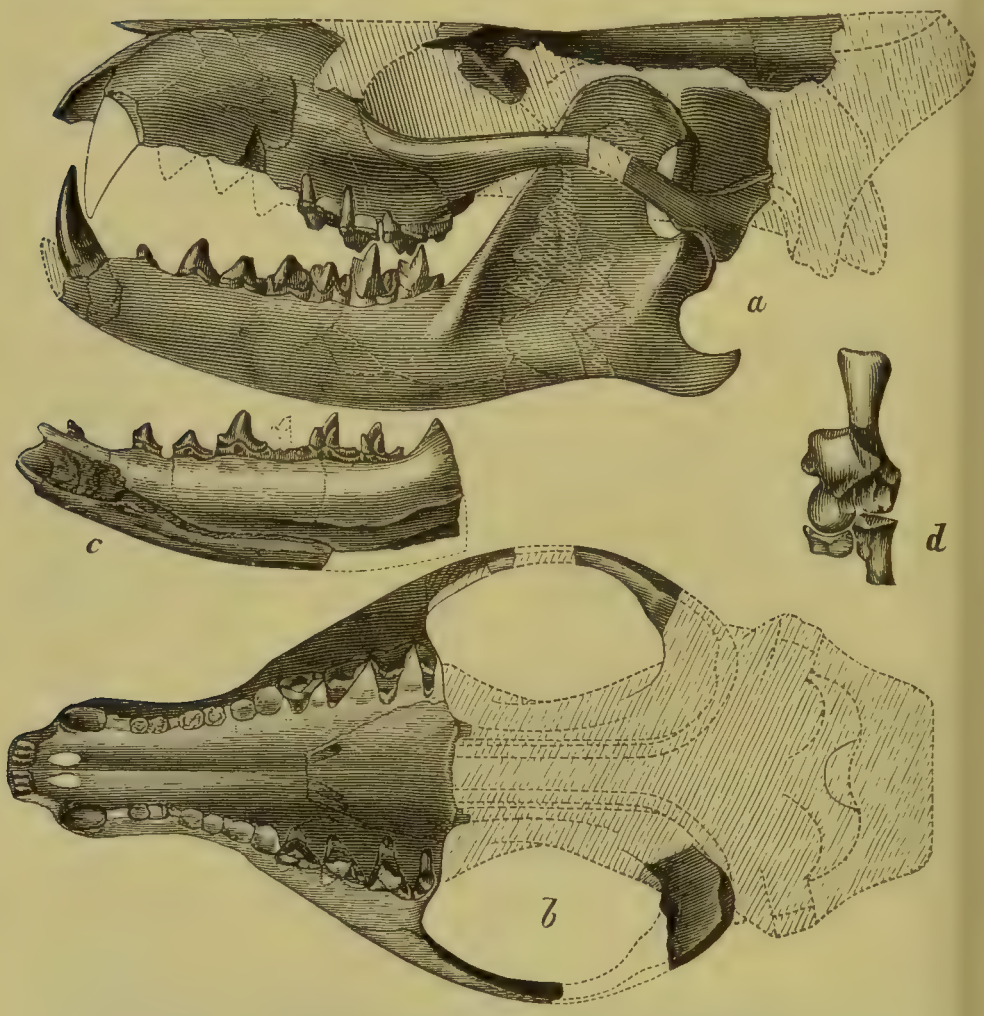


Fig. 1338.—Skull (*a*, *b*, *c*) and tarsus (*d*) of *Proviverra Whitiæ*; from the Wasatch Eocene of Wyoming, U.S.A. Two-thirds natural size.

true molars, and by the presence of an inner cusp to the blade of those of the lower jaw. The type genus *Proviverra* (*Cynohyænodon* or *Stypolophus*) occurs in the Upper Eocene of both Europe and North America; one of the European forms being from the Quercy Phosphorites. The skull (fig. 1338) is elongated, and the lower true

molars, which are differentiated into a blade and a hinder tubercular talon, closely resemble the lower carnassial of *Dasyurus* (fig. 1145) among the Marsupials, and of *Cynodictis* and *Viverra* in the Carnivora Vera, and thus indicate how the latter group has in all probability been derived from a form allied to the present family; the hinder lower molars of the Carnivora Vera having become tubercular and non-secant. Other members of this family found in the Lower, or Puerco, Eocene of North America are *Deltatherium*, *Chriacus*, and, according to Professor Cope, *Mioclænus*, and probably *Triïsodon* and *Onychodectes*. *Didelphodus*, from the higher Eocene of America, may also be placed here, as well as *Quercytherium*, from the French Phosphorites, and perhaps *Galethylax*, of the Paris Eocene. *Conoryctes* and *Hemiganus* are allied Puerco types; the latter being distinguished by the fusion of the roots of the upper true molars, and hence regarded by Professor Cope as the type of a distinct family showing signs of affinity with the Tillodontia.

Family Arctocyonidæ.—This family is typified by the genus *Arctocyon*, of the Lower Eocene of France, with which may be classed *Hyodectes* and *Heteroborus*, of the Lower Eocene of Rheims. Dr Schlosser suggests that *Mioclænus* should come in this family.

Family Mesonychidæ.—The members of this family are short-jawed forms, usually having the typical number of teeth, which are less different than in the other families from those of the Carnivora Vera. The type genus *Mesonyx*, from the North American Eocene, has a grooved astragalus; and other genera which are referred to this family are *Dissacus*, *Sarcothraustes*, and *Patriofelis*, from the latter area, and not improbably *Theuritherium*, of the French Phosphorites. *Dissacus* has, however, no trochlea to the astragalus, and is therefore nearer to the *Proviverridæ*. *Amblyctonus*, of the North American Eocene, is an allied form with the astragalus not grooved, on which account it has been regarded as the type of a distinct family. *Palæonictis*, of the Lower Eocene of France, may be allied.

Family Uncertain.—A few genera cannot at present be definitely placed. These comprise *Thylacomorphus*, from the French Phosphorites, which it has been suggested may be identical with *Proviverra;* and *Dasyurodon*, or *Apterodon*, from the Lower Miocene (Middle Oligocene) of Flonheim, which Dr Schlosser thinks may turn out to be the same as *Oxhyæna galliæ*. *Dromocyon*, of the Bridger Eocene, is not improbably founded upon a very old individual of *Mesonyx;* while the imperfectly known *Argillotherium*, from the London Clay, may prove to be identical with one of the American genera. Finally, it should be mentioned that Dr Schlosser would place in this suborder the genus *Platychœrops*, which is here classed with the Tillodontia.

CHAPTER LXIII.

CLASS MAMMALIA—continued.

Orders Insectivora, Chiroptera, and Primates.

Order IX. Insectivora.—The Insectivora are a group of small Mammals, not very readily defined from the characters of their bones and teeth. The teeth are well developed, and generally easily separable into the usual four divisions, although in certain cases the distinction between incisors, canines, and premolars is not very clear. The dentition is diphyodont and heterodont; the cheek-teeth are always rooted, and their crowns carry a number of minute pointed cusps; the crowns of the upper true molars being either subquadrangular or triangular in shape. The first pair of incisors in some cases are not in contact in the middle line; and the canines are often weak. The zygomatic arches of the skull are usually either weak or entirely absent; clavicles are present in all existing forms except *Potamogale;* in the carpus the scaphoid and lunar are separate; the feet are usually either entirely or partially plantigrade, and their digits are generally five in number, with the terminal phalangeals unguiculate, narrow, and subcylindrical. Certain Insectivores, such as the Moles and *Galeopithecus*, are remarkable as being the only Mammals in which ossified vertebral intercentra are known to have been developed in the dorso-lumbar region. As a rule the humerus has a foramen.

Fossil forms apparently indicate a relationship on the one hand with the Creodont Carnivora, and on the other with the Lemuroid Primates; those genera with square-crowned upper true molars approximating to the latter group, while those in which the crowns of these teeth are triangular show the nearest affinity to the former. Dr Schlosser concludes, with great probability, that the Lemuroids, Insectivores, and Creodonts are all diverging branches from a common stock, which may also have given origin to the Condy-

larthrous Ungulates. The resemblance of the molars of *Tupaia* to those of the Marsupial genus *Perameles*, and that between the same teeth in the Creodonts and the *Dasyuridæ*, further suggests the connection of this common stock with the ancestral types of the Polyprotodont Marsupials.[1] The Insectivores agree with the Lemuroids not only in dental characters, but also in the presence of clavicles, in their plantigrade feet, and the discoidal placenta; and it is indeed quite evident that the ancestral stock of the Primates must have been provided with complete clavicles.

This order may be divided into the suborders Insectivora Vera and Dermoptera. The former may be further subdivided into two sections, in the first of which the molars have broad and squared crowns, with their cusps frequently arranged like the letter W, while in the second section the crowns of these teeth are narrow and V-shaped, with the apex of the V directed inwardly (tritubercular). The Dermoptera, represented only by the volant genus *Galeopithecus*, are unknown in a fossil condition. It should, however, be observed that this genus, although not on the direct line of descent, indicates the manner in which the Insectivores have become modified into the Bats. The first section of the Insectivora Vera comprises the existing *Tupaiidæ*, *Macroscelididæ*, *Erinaceidæ*, *Soricidæ*, and *Talpidæ*, together with the extinct *Microchœridæ* and *Dimylidæ*.

Family Tupaiidæ.—The Tupaias are small arboreal Insectivores confined at the present day to the Indo-Malayan region. The genus *Parasorex*, from the Middle Miocene of the Continent, has the dental formula $I.\frac{3}{3}$, $C.\frac{1}{1}$, $Pm.\frac{4}{4}$, $M.\frac{3}{3}$, and may be provisionally placed in this family, although, according to Dr Schlosser, it approximates in several respects to the *Macroscelididæ*. There is one more upper incisor and one more premolar in each jaw than in *Tupaia*, and the last two premolars are somewhat more complex. The above-mentioned writer regards this genus as the representative of a group connecting the *Tupaiidæ* of Asia with the *Macroscelididæ* of Africa. An Insectivore from the Middle Miocene of Sansan, described as *Lantanotherium*, is said to be very nearly allied to *Tupaia*.

Family Erinaceidæ.—Since the *Macroscelididæ* are at present unknown in a fossil state, we may pass to the *Erinaceidæ* or Hedgehogs. In the typical genus *Erinaceus* (fig. 1339) the dental formula is $I.\frac{3}{2}$, $C.\frac{1}{1}$, $Pm.\frac{3}{2}$, $M.\frac{3}{3}$; the first pair of upper incisors are large,

[1] On embryological grounds some authorities are disposed to regard the Marsupials as being off the line of Eutherian ancestry; but it must be borne in mind that the evidence only includes existing types.

and separated from one another by a space, the five succeeding teeth small and conical, the last premolar and the two first true molars broad and cusped, while the last tooth is very small; and there is a vacuity on either side of the hinder part of the palate. The existing *E. europæus* has been found fossil in the Pleistocene; a small species occurs in the Upper Miocene of Œningen, in Switzer-

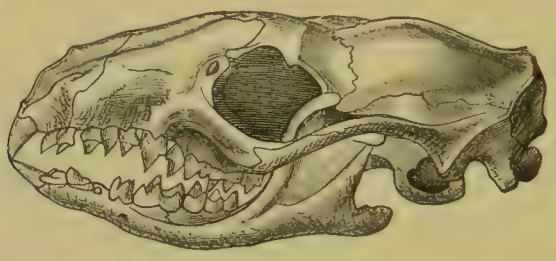


Fig. 1339.—Left lateral view of the skull of the Hedgehog (*Erinaceus europæus*).

land, and others are found in the Middle Miocene of France. In the Lower Miocene of the same country occurs the genus *Palæoerinaceus*, distinguished from *Erinaceus* by the absence of vacuities in the palate, and the greater relative width of the latter. An apparently allied form from the French Miocene has been described by Gervais under the name of *Erinaceus arvernensis*, which is, however, not the same as *E. arvernensis* of De Blainville. From the Quercy Phosphorites there have been obtained remains of other members of this family more nearly allied to the existing *Gymnura* of Madagascar, but presenting characters which also link them very closely with *Erinaceus* through *Palæoerinaceus*. These Quercy forms have been referred to three genera under the names of *Neurogymnurus*, *Cayluxotherium*, and *Comphotherium*, but it appears probable that the second is a synonym of the first. The teeth of *Neurogymnurus* and *Cayluxotherium* are like those of *Gymnura*, but the palate has vacuities as in *Erinaceus*; *Comphotherium* is distinguished by a cingulum to the lower true molars, which also occurs in *Gymnura*. *Neurogymnurus* has also been recorded from the Upper Eocene of Hampshire.

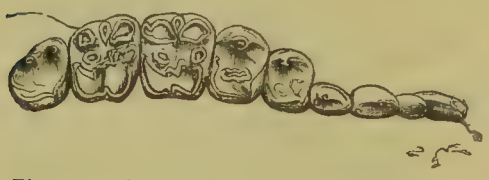


Fig. 1340.—Palatal view of the right upper cheek-dentition of *Microchœrus erinaceus*; from the Upper Eocene of Hordwell.

Family Microchœridæ.—The genus *Microchœrus* (fig. 1340), from the Upper Eocene of Hordwell, with which *Heterohyus*, of the corresponding beds of France, may be identical, agrees with *Erinaceus* in showing an interval between the first upper incisors of either side, and may be provisionally placed in this order. It has

been regarded as allied to the Lemuroid *Hyopsodus*, but Professor Osborn states that it is really very different. The dental formula may be given approximately as $I.\ \frac{2}{?}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{3}{?}$, $M.\ \frac{3}{3}$. The two upper incisors have compressed crowns, somewhat like those of the two succeeding teeth; but the last two premolars and the true molars have broad and flat crowns, carrying a number of small cusps.

Family Dimylidæ.—This family is proposed by Dr Schlosser for the genera *Dimylus* and *Cordylodon;* two minute Insectivores from the European Miocene which appear to be related to the *Erinaceidæ*.

Family Soricidæ.—The *Soricidæ*, or Shrews, are readily characterised by their dentition, in which the first upper incisor is large and furnished with a basal tubercle, while between it and the last premolar there are a variable number of small incisors and premolars, together with the equally minute canine. In the mandible the number of teeth is always *I.* 1, *C.* 1, *Pm.* 1, *M.* 3; the incisor being proclivous and much produced forwards, and the canine the smallest tooth of the series. Existing species of *Sorex*, and perhaps of *Crossopus*, occur in the Norfolk Forest-bed, while a species of the former genus, regarded as extinct, has been recorded from the Pleistocene breccias of Sardinia. Existing species of *Sorex* or *Crocidura* also occur in the caverns of Madras. Numerous forms have been recorded from the Continental Tertiaries, ranging from the Miocene to the Quercy Phosphorites, some of which are referred to *Sorex*, while others, such as the Quercy species, have been regarded as generically distinct, and named *Amphisorex*. Dr Schlosser thinks that *Orthaspidotherium* and *Pleuraspidotherium*, mentioned on p. 1288, might be placed here.

Family Talpidæ.—The *Talpidæ*, or Moles and Desmans, are closely allied to the *Soricidæ*, although easily distinguished by the non-production of the first lower incisor; they are usually of fossorial, but in some cases are of natatorial habits. This family is divided into the *Myogalinæ* and the *Talpinæ;* in the former the humerus and clavicle being moderately elongated. In this subfamily the aquatic type genus *Myogale*, in which the dentition (fig. 1341) is $I.\ \frac{3}{3}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{4}{4}$, $M.\ \frac{3}{3}$, is represented in the Norfolk Forest-bed by the existing Desman (*M. moschata*), of the rivers of Russia; the fossil form having been originally described under the name of *Palæospalax*. Remains of this genus have also been obtained from the Middle and Lower Miocene of France. *Tetracus*, from the Lower Miocene of Ronzon, near Puy-en-Velay, is a small Insectivore apparently presenting affinities both with *Myogale* and *Erinaceus;* and allied to this genus are two other imperfectly known

forms from the French Lower Miocene, to which the names *Echinogale* and *Mysarachne* have been applied. These genera, and perhaps the following one, seem to show indications of a transition between the existing members of the *Erinaceidæ*, *Soricidæ*, and *Talpidæ;* and thus, together with the imperfect nature of the remains by which they are known, render the determination of their serial position a matter of great difficulty. The French Lower Miocene has also yielded the allied genus *Plesiosorex* (fig. 1342), which appears to have belonged to the present subfamily, but is only known by the mandible, in which there are ten teeth. The smaller *Amphidozotherium*, from the Quercy Phosphorites, is said to be allied to the existing fossorial genus *Urotrichus* of Japan and North America. In the second subfamily, or *Talpinæ*, in which the humerus and clavicle are of enormous relative breadth, the typical genus *Talpa* (fig. 1343) has the same dental formula as in *Myogale*. The common Mole, *T. europæa*, occurs fossil in the Norfolk Forest-bed, while a species from the Pleistocene breccia of Sardinia is regarded as peculiar, and named *T. tyrrhenaica*. The genus itself is apparently as old as the Lower Miocene, although the species (*T. telluris*) from the middle stage of that period has been distinguished by some writers as *Hyporyssus*, and the one from the lower stage (*T. acutidens*) as *Geotrypus*.[1] The Quercy Phosphorites have yielded a very closely allied form, which is, however, regarded by its describer as generically distinct, and named *Protalpa cadurcensis*. From the Eocene of North America an allied genus has been described under the name of *Talpavus;* but the so-called *Herpetotherium*, of the Miocene of the same country, which has been regarded as related to the Moles, is referred to *Didelphys* (fig. 1151, p. 1281).

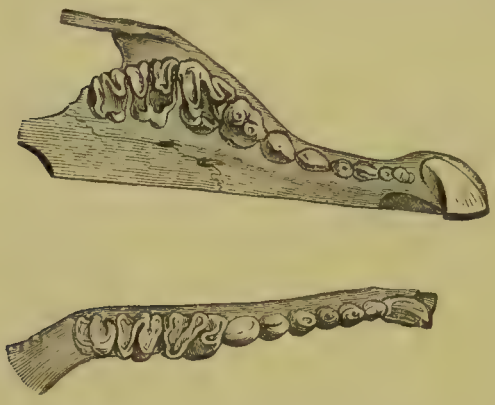


Fig. 1341.—Palatal view of right upper and lower dentition of *Myogale moschata*. Europe.

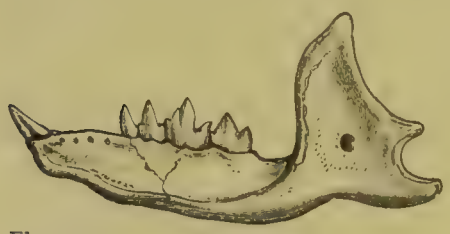


Fig. 1342.—Left ramus of lower jaw of *Plesiosorex soricinoides*, wanting the last true molar and the teeth between the first incisor and the fourth premolar; from the Lower Miocene of the Auvergne. Twice natural size. (After De Blainville.)

[1] Preoccupied by *Geotrupes* in the Coleoptera.

Family Adiposoricidæ.—This family contains the minute *Adiposorex* and *Adiposoriculus*, from the Lowest Eocene of Rheims, which Dr Schlosser regards as related to the Shrews, but forming a distinct family, attaining a higher degree of development.

Family Leptictidæ (Ictopsidæ).—The second section of the Insectivora Vera includes the recent families *Potamogalidæ*, *Solenodontidæ*, *Centetidæ*, and *Chrysochloridæ;* and we may provisionally place in the same neighbourhood the family *Leptictidæ* of the North American Eocene and Miocene. The latter forms are regarded by Dr Schlosser as true Insectivora, although they were placed by Professor Cope near the *Hyænodontidæ*. The family includes the genera *Leptictis*, *Mesodectes*, *Ictops*, and perhaps *Geolabis*.



Fig. 1343.—Lateral view of right dentition of the Mole (*Talpa europæa*). Enlarged.

Finally the names *Centetodon*, *Entomodon*, *Entomacodon*, *Centracodon*, and others have been applied to the remains of small entomophagous mammals from the Lower Tertiaries, of which the serial position is doubtful.

Order X. Chiroptera.—The Chiroptera are characterised by the fact that the anterior limbs are longer than the posterior, the digits of the fore limb, with the exception of the pollex, being enormously elongated (fig. 1344). These elongated fingers are united by an expanded membrane or patagium, which is also extended between the fore and hind limbs and the sides of the body, and in many cases passes also between the hind limbs and the tail. The patagium thus formed is naked, or nearly so, on both sides, and serves for flight. In the manus the pollex, and sometimes the next digit as well, is unguiculate, or furnished with a claw; but the other digits are destitute of nails. In the hind limbs all the toes are unguiculate, and the hallux is not in any respect different from the other digits. Well-developed clavicles are always present, and the radius has no power of rotation upon the ulna. The four kinds of teeth are always present (although the molars are aborted in *Desmodus*), and the dental formula is never known to exceed

$$I.\ \frac{2}{3},\ C.\ \frac{1}{1},\ Pm.\ \frac{3}{3},\ M.\ \frac{3}{3}.$$

This order, which is evidently a branch from the Insectivorous stock, is divided into the suborders Megachiroptera and Microchiroptera. The former, which is characterised by the possession of smooth cheek-teeth, marked by a longitudinal groove, comprises

the *Pteropodidæ*, or Fruit-bats, and is unknown in a fossil condition. In the latter, which comprises all other Bats, the teeth are covered with minute pointed cusps; nearly all the species being of comparatively small size. The most remarkable feature presented in the past history of this order is the occurrence of forms closely

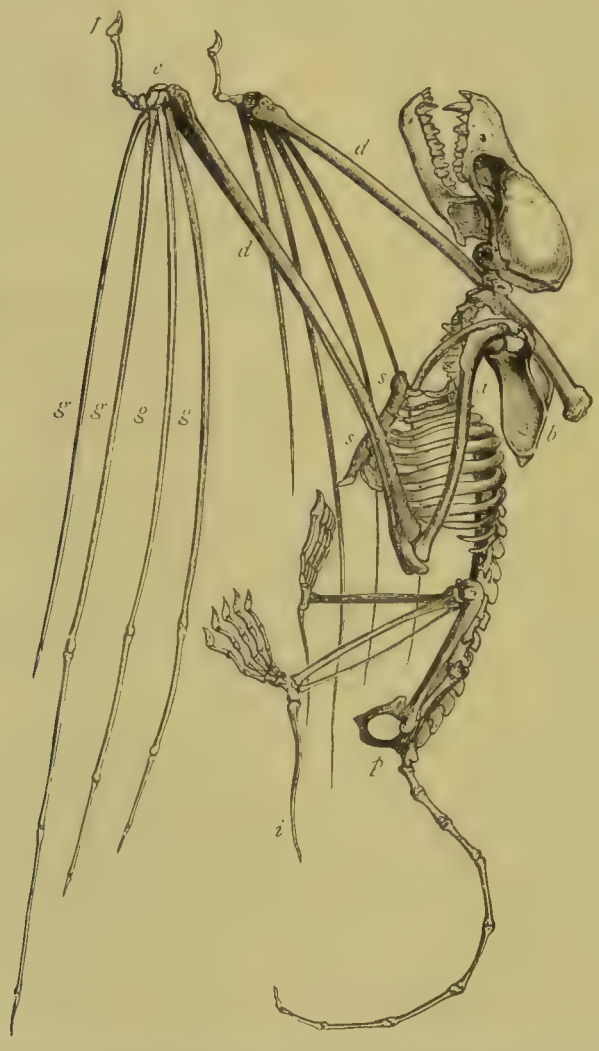


Fig. 1344.—Skeleton of the Mouse-coloured Bat (*Vespertilio murinus*). *a*, Humerus; *b*, Scapula; *d*, Radius, with the rudimentary ulna at its proximal end; *c*, Carpus; *f*, Pollex; *g g*, Metacarpals; *s s*, Sternum; *p*, Pelvis; *i*, Supplementary bone attached to the calcaneum.

allied to those of the present day as low down as the Bridger Eocene of North America, which indicates that the characteristic features of the order were probably acquired at a period not later than the Lower Eocene or Cretaceous epoch. The following families of *Microchiroptera* may be noticed:—

Family Rhinolophidæ.—In the existing genera of this family the dental formula never exceeds *I.* $\frac{1}{2}$, *C.* $\frac{1}{1}$, *Pm.* $\frac{2}{3}$, *M.* $\frac{3}{3}$, and the nose carries a peculiar leaf-like expansion. The type genus *Rhinolophus*, in which the dental formula is as above, is represented in the cave-deposits of Europe by remains of existing species. Two Bats, from the Upper Eocene Phosphorites of France, have been referred to this genus under the names of *R. dubius* and *R. antiquus*, but the latter species is regarded by some authorities as entitled to generic distinction, and the term *Pseudorhinolophus* has accordingly been proposed for its reception. *Alastor*, from the same deposits, is an extinct genus characterised by the extreme shortness of the nasal region and other features of the skull. *Palæonycteris*, from the Lower Miocene of France, is stated to be allied to *Rhinolophus*, but the premolars are $\frac{3}{3}$, and the limb-bones are said to resemble those of the South American *Molossus*. *Phyllorhina*, in which the premolars are $\frac{(1-2)}{2}$, is represented by the living oriental *P. diadema* in the Pleistocene cave-deposits of Madras, and perhaps by a species in the Quercy Phosphorites.

Family Vespertilionidæ.—In the *Vespertilionidæ* the nose does not carry a distinct follicular appendage, the number of incisors is usually $\frac{(1-2)}{3}$, and in some genera there are three premolars in each jaw. Of *Plecotus*, the existing *P. auritus* occurs in the cavern-deposits of Europe. *Vesperugo*, with incisors usually $\frac{2}{3}$, and premolars $\frac{2}{2}$, is perhaps represented in the Upper Eocene of the Paris basin by the well-known *V. parisiensis*, which appears closely allied to the existing *V. serotina*, although generically separated by some writers under the name of *Nyctitherium*. This genus has also been described from the Eocene of North America, where it is represented by several species, ranging as low down as the Bridger horizon, some of which have been described under the name of *Nyctitherium*. *Nyctilestes serotinus*, from the same deposits, is the type of an allied genus. Remains of the existing *V. noctula* (fig. 1345) occur in the English Pleistocene. In the type genus *Vespertilio* the dental formula is *I.* $\frac{2}{3}$, *C.* $\frac{1}{1}$, *Pm.* $\frac{3}{3}$, *M.* $\frac{3}{3}$. The existing *V. murinus* occurs in the cave-deposits of France, and a considerable number of species have been referred to this genus from the Middle Tertiaries of the Continent, but the generic reference must be con-

sidered in some instances as open to doubt. Among these may be mentioned *V. murinoides*, from the Middle Miocene of France, and *V. precox* and *V. insignis*, from the Lower Miocene of Germany. A Bat from the Quercy Phosphorites originally named *V. Bourguignati* has been made the type of a distinct genus *Vespertiliavus*,

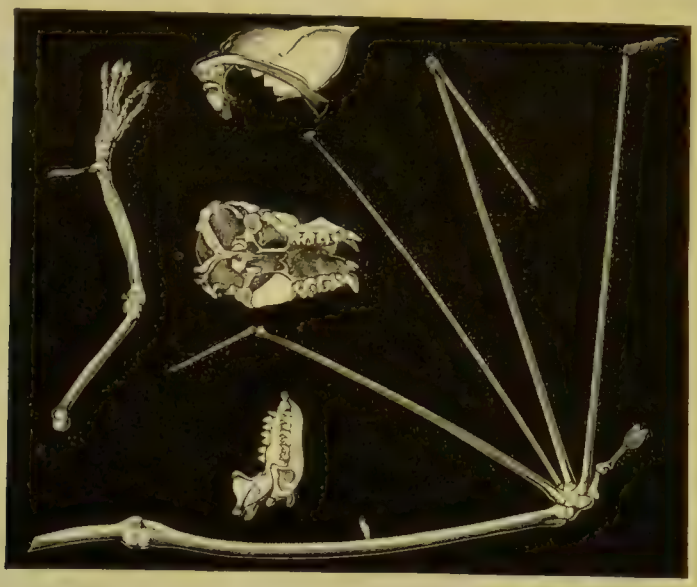


Fig. 1345.—*Vesperugo noctula*.[1] Skull, scapula, and fore and hind limbs; from a fissure in the Mendip Hills.

and differs from *Vespertilio* in the proportions of the premolars. Remains of numerous existing members of this family have been recorded from European caverns.

Family Emballonuridæ.—This is an extensive family showing great variation in the number of the teeth, and mainly characterised by the nose and muzzle being devoid of expansions, and by certain peculiar features connected with the tail. All its members at the present day are confined to tropical and subtropical regions. In *Taphozous*, of which the dental formula is $I.\frac{1}{2}$, $C.\frac{1}{1}$, $Pm.\frac{2}{2}$, $M.\frac{3}{3}$, remains of the existing *T. saccolæmus* occur in the cave-deposits of Madras; and Dr Weithofer considers that certain humeri from the Quercy Phosphorites may indicate the occurrence of this genus in the Upper Eocene. In the Brazilian cave-deposits we meet with remains of a *Molossus* (*Dysopes*), probably identical with the living *M. Temmincki* of the same region.

Family Phyllostomatidæ.—The last family is that of the *Phyl-*

[1] In the previous edition this figure was wrongly named *V. parisiensis*.

lostomatidæ, now confined to tropical America, and distinguished by the presence of cutaneous expansions in the nasal region, as well as by a peculiarity in the number of the digits of the manus. In this family the existing *Vampyrus spectrum*, having the dental formula $I.\ \frac{2}{2}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{2}{3}$, $M.\ \frac{3}{3}$, together with several undetermined species of *Phyllostoma* (fig. 1346), in which the premolars are $\frac{2}{2}$, occur in the cave-deposits of Brazil. Curiously enough the mandible of a large Bat, from the Quercy Phosphorites, described under the name of *Necromantis*, appears to indicate the occurrence of this family in the European Eocene.



Fig. 1346.—Lateral view of the skull of the Javelin Bat (*Phyllostoma hastatum*).

In conclusion it should be observed that Professor Cope thinks that a small Mammal from the Miocene of North America, which he has described under the name of *Domnina*, may possibly belong to the Chiroptera.

Order XI. Primates.—This, the highest order of Mammals, comprises the Lemurs, Monkeys, Baboons, Apes, and Man. The digits are unguiculate, and usually five in number; and in existing forms, with the exception of Man, the hallux is opposable to the other digits. The pollex may be wanting, but when present is usually opposable to the other digits of the manus. The dentition is diphyodont and heterodont. In the existing and the allied extinct genera the incisors are usually $\frac{2}{2}$, and the true molars (with the exception of the *Hapalidæ*) $\frac{3}{3}$ in number. The crowns of the cheek-teeth are, moreover, always adapted for grinding, and those of the true molars generally consist of four tubercles, or cusps, which may either be simple, or modified so as to form imperfect transverse ridges or crescents; but some extinct types have tritubercular upper molars.

The structure of the premolars is always simpler than that of the true molars; and in many Lemuroids the anterior lower premolar assumes the form and functions of a canine, as in the *Cotylopidæ* (fig. 1347). All existing forms have the orbit entirely surrounded by bone; while complete clavicles are present, and there is

no entepicondylar foramen to the humerus, nor a third trochanter to the femur. The terminal phalangeals of the digits are flattened. In the soft parts there is a discoidal placenta, as in the Insectivora.

In our present state of knowledge, it is difficult to draw a line between the more generalised fossil representatives of this order and the Insectivora. Some remarks on the probable origin of the Primates have been already made under the head of the last-named order, while others are added below.

Suborder 1. Lemuroidea.—The existing members of this group differ in many respects from the following suborder, but attention may be directed mainly to certain osteological and dental characters. Thus the skull (fig. 1347) has a somewhat produced muzzle; the orbits are not closed behind by bone, but open freely beneath the post-orbital bar into the temporal fossa; and the lachrymal foramen is situated on the outer surface of the skull, instead of within the orbit. The nostrils have a peculiar twist on the outer side. The incisors vary much in the different families, but they are frequently separated in the middle line, and are usually $\frac{2}{2}$ in number, although they are reduced to $\frac{1}{1}$ in *Chiromys*; those of the lower jaw being frequently procumbent. Canines are present except in *Chiromys*. The number of premolars varies from $\frac{1}{0}$ in *Chiromys* to $\frac{4}{4}$ in the extinct *Adapis*, but is generally either $\frac{2}{2}$ or $\frac{3}{3}$; while frequently the second lower premolar is larger than either of the following teeth. The outer tubercles of the upper true molars (fig. 1349) are laterally flattened, while the inner ones form imperfect crescents; and in the lower molars the tubercles likewise form a pair of imperfect crescents. The second digit of the pes has a long claw-like nail, but all the other digits have nails; the digits themselves being five in number, and the long pollex being generally opposable. The brain has but few convolutions, and the cerebellum is only partially covered by the cerebrum.



Fig. 1347.—Left lateral aspect of the skull of the Slow Loris (*Nycticebus tardigradus*); from the Malayan region. The tusk-like tooth in the lower jaw is the second premolar. (After Giebel.)

Many of the foregoing characters are common to other orders,

such as the Insectivora. In the case of fossil forms it appears, indeed, that the Lemuroids can only be distinguished from the Insectivores by the absence of the cleft in the terminal phalangeals of the digits, so that when these are unknown it is frequently very difficult, if not impossible, to determine to which order such forms should be referred. Since, moreover, as we have stated under the head of the Insectivora, it is probable that Insectivores and Lemuroids are descended from the same ancestral stock we must expect to find the characters common to the two groups increasing in importance and number as we recede in time. By Professor Cope the Lemuroids are, however, regarded as closely allied to the Condylarthrous Ungulates; and that writer proposes to brigade together the Primates, Condylarthra, and Hyracoidea under the common name of Taxeopoda; the Condylarthra being regarded as the ancestral type. Now although we may be prepared to admit the derivation of the Condlyarthra from the common stock which gave origin to the Insectivora and Primates (see p. 1455), yet the apparent absence of clavicles in all the known representatives of that group renders it at least premature to say definitely that it gave rise to the Primates. At the present day Lemuroids are confined to the warmer regions of the Old World, being especially characteristic of Madagascar and certain parts of Africa. The recent forms are divided into the families *Lemuridæ*, *Tarsiidæ*, and *Chiromyidæ*.

Family Hyopsodontidæ.—This family name was proposed by Dr Schlosser[1] for the reception of certain North American Eocene forms now looked upon by most writers as undoubted Lemuroids, although some of them have been classed among the Insectivora. The most generalised form is *Pelycodus*, from the Eocene of New Mexico, at one time regarded by Professor Cope as an Insectivore allied to *Tupaia*. Dr Schlosser states that it presents some affinity to the Insectivorous *Microchœrus*, which he places in the same family. *Hyopsodus* (fig. 1348), of the American Eocene, has the dental formula $I.\frac{2}{2}$, $C.\frac{1}{1}$, $Pm.\frac{4}{4}$, $M.\frac{3}{3}$; the third upper premolar is as well developed as the second, by which character it is readily distinguished from *Microchœrus*, to which it has been compared. Several species have been described, of which one comes from the Lower or Puerco Eocene, while the others are from the higher Wasatch and Bridger horizons. *Microsyops* is



Fig. 1348.—Palatal view of the left upper (*a*) and lower (*b*) dentition of *Hyopsodus vicarius*; from the Eocene of North America. (After Cope.)

[1] Wrongly given as *Hyopsodidæ*.

an apparently allied form from the North American Eocene said to have only three premolars. In *Pelycodus* the hallux was not opposable. There are a number of other names which have been applied to American forms of uncertain position, but since the synonymy is very complex nothing would be gained by quoting them here.

Family Lemuridæ.—Passing to Lemuroids more closely allied to existing forms those extinct genera may first be noticed many of which exhibit the generalised feature of having four premolars in either jaw, on which grounds, coupled with certain slight differences in the form of the lower premolars, Dr Schlosser regards them as constituting a distinct family—the *Adapidæ*. We may, however, provisionally follow Professor Flower in including them in the *Lemuridæ*, of which they will form the subfamily *Adapinæ*. The best known of these forms is the type genus *Adapis* (*Aphelotherium*, or *Palæolemur*), from the Upper Eocene (Oligocene) of both France and England, in which the dental formula is $I.\ \frac{2}{2},\ C.\ \frac{1}{1},\ Pm.\ \frac{4}{4},\ M.\ \frac{3}{3}$; the upper molars being of a quadritubercular type. The last upper premolar is as complex as the true molars, which (fig. 1349) resemble those of *Lepidolemur* and *Hapalemur*, while the skull makes the nearest approach to that of *Propithecus*. It has, indeed, been suggested that this and the allied genera show certain relationships to the Anthropoidea which are not seen in existing representatives of the suborder; but their alleged relationship to the bunodont Artiodactyla does not appear to be substantiated. The imperfectly known genus *Cænopithecus* from the Upper Eocene of Switzerland is regarded by Dr Schlosser as identical with *Adapis*, although Professor Rütimeyer considers that it is allied to the American *Pelycodus*. From the Eocene of North America we have the two nearly related genera *Tomitherium* and *Notharctus*. The former (with which *Limnotherium* of Professor Marsh is identical) is distinguished by the single roots to the premolars, and by the development of a third lobe to the last lower true molar. *Notharctus* agrees with *Adapis* in the presence of two roots to the premolars, but has a larger lower canine. *Thinolestes* and *Telmatolestes* are probably allied to or identical with the preceding genera; both being from the American Eocene.



Fig. 1349.—Palatal aspect of the left upper cheek-teeth of *Adapis magna*; from the Upper Eocene of Hampshire.

Turning to the more typical representatives of the family, in which at least the upper premolars do not exceed three, we have the small

Necrolemur from the French Phosphorites, the dental formula of which Dr Schlosser gives as $I.\ \frac{2}{1}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{3}{3}$, $M.\ \frac{3}{3}$, or the same as in the existing *Tarsius*, although he suggests that in some cases there may have been four lower premolars. The skull resembles that of the living genus *Galago* of Africa, both in size and structure, as is especially shown by the prominent auditory bullæ. The upper molars are also like those of one species of that genus, although the

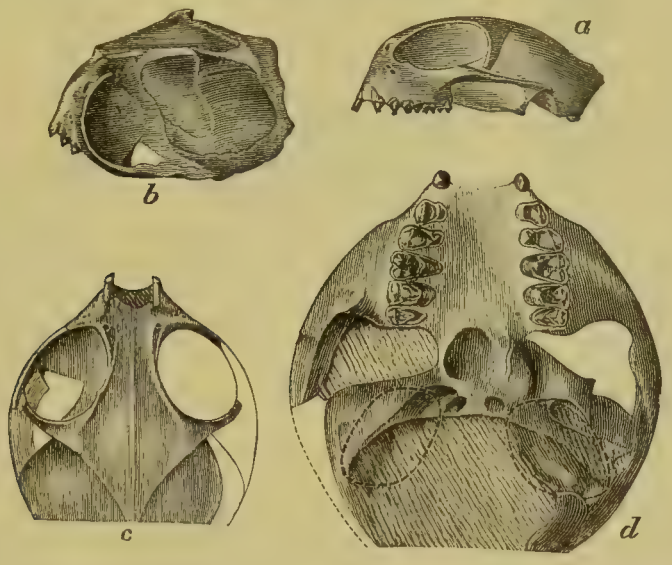


Fig. 1350.—Cranium of *Anaptomorphus homunculus;* from the Wasatch Eocene of North America. *a*, From the left side; *b*, Oblique view; *c*, From above; *d*, From below (enlarged). (After Cope.)

last premolar is distinguished by having only one outer column, and is accordingly simpler than the true molars. In this respect *Necrolemur* agrees with *Chirogaleus* of Madagascar.

Plesiadapis, from the Lower Eocene of Rheims, may be provisionally placed here. *Anaptomorphus*, from the Middle Eocene of North America, of which the cranium and mandible are shown in the accompanying figures, seems to be allied to *Necrolemur*, but has two lower incisors, and the upper premolars are unusually complex and approach those of the *Anthropoidea*. The upper molars are tritubercular; and Professor Cope gives the dental formula as $I.\ \frac{2}{2}$, $C.\ \frac{1}{1}$, $Pm.\ \frac{2}{2}$, $M.\ \frac{3}{3}$. *Cynodontomys* is an imperfectly known genus from the Wasatch Eocene; and *Mixodectes* an older one from the Puerco or Lower Eocene of North America. Dr Schlosser also regards the American Eocene genus *Omomys* as allied to *Necrolemur*,

although it was considered by Professor Cope to be more nearly related to *Hyopsodus*. *Lemuravus*, of the American Eocene, may perhaps belong to the preceding division of this family.

The total absence of remains of Lemuroids from the Miocene of

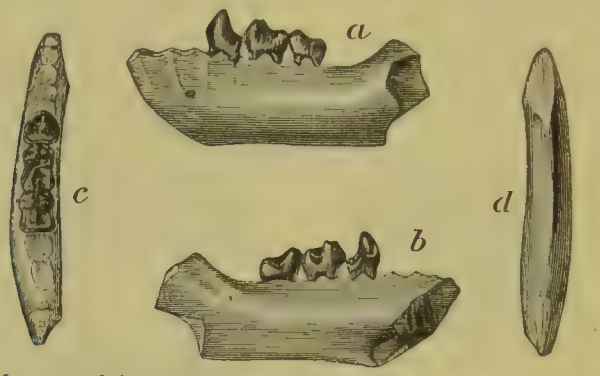


Fig. 1351.—Left ramus of the mandible of *Anaptomorphus æmulus*, wanting all the teeth except the last premolar and first two true molars; from the Bridger Eocene of North America. *a*, Outer; *b*, Inner; *c*, Upper; *d*, Lower view. Twice natural size. (After Cope.)

Europe and North America points to their early disappearance from those regions.

Suborder 2. Anthropoidea.—In all the known members of this suborder the number of the incisors is $\frac{2}{2}$; the upper ones being always in contact in the middle line, and the lower ones not projecting forwards to any great extent. The orbit is completely closed behind by bone; and the lachrymal foramen opens within its cavity. The pollex is short, and the second digit of the pes has a true nail. This suborder may be divided into the *Platyrhine* and *Catarhine* sections. In the former, which is confined at the present day to South America, the structure of the cheek-teeth is intermediate between that obtaining in the Lemuroidea and the succeeding section. The premolars are always $\frac{3}{3}$ in number, but the true molars may be either $\frac{2}{2}$ (*Hapalidæ*), or $\frac{3}{3}$ (*Cebidæ*); and the last lower true molar has a small hind talon. The nostrils are simple, widely separated, and placed nearly at the extremity of the snout. The pollex is either absent, or, if present, is not opposable; and there are other characteristic external features.

The genus *Laopithecus*, from the Miocene of North America, has been referred to this section, but its dentition approximates to that of the early Lemuroids, and its position must be regarded as unsettled.

Family Hapalidæ.—In the Marmosets, which are nearest to the

Lemuroidea, two species of *Hapale* have been recorded from the cave-deposits of Brazil, one of which is regarded as extinct.

Family Cebidæ.—The Brazilian cave-deposits have also yielded remains of various *Cebidæ* referable to the existing genera *Callithrix*, *Cebus*, and *Mycetes;* several of which appear indistinguishable from species still inhabiting the same region. A monkey allied to *Mycetes*, but of larger size than any existing species, has been referred to a distinct genus under the name of *Protopithecus*.

Catarhine Section.—In this section, which comprises the three families *Cercopithecidæ*, *Simiidæ*, and *Hominidæ*, the number of the cheek-teeth is always $Pm.\ \frac{2}{2}$, $M.\ \frac{3}{3}$, and the crowns of the true molars are either transversely ridged or simply tubercular. The nostrils are straight, and placed close together, and their septum is narrow. In all except *Colobus*, where it is absent, the pollex is opposable to the other digits. The tail is never prehensile, and may be wanting; while cheek-pouches and ischial callosities are often present. With the exception of one species, which occurs at Gibraltar, all the existing *Cercopithecidæ* and *Simiidæ* are confined to Asia and Africa.

Family Cercopithecidæ.—In this family, which includes most of those Old World genera commonly termed Monkeys and Baboons, the tubercles of the true molars are developed into a pair of imperfect transverse ridges, and the third lower true molar has a hind lobe or talon. It has been stated that the genus *Colobus* occurs in the Miocene of Bavaria, but the specimen on which this determination was made really belongs to the Artiodactylate genus *Cebochœrus*. The somewhat widely spread genus *Macacus* is represented in the Pliocene Siwaliks of India, and also in the Upper Pliocene of the Continent and the Pleistocene of India; one of these continental species having probably been described under the name of *Aulax-*

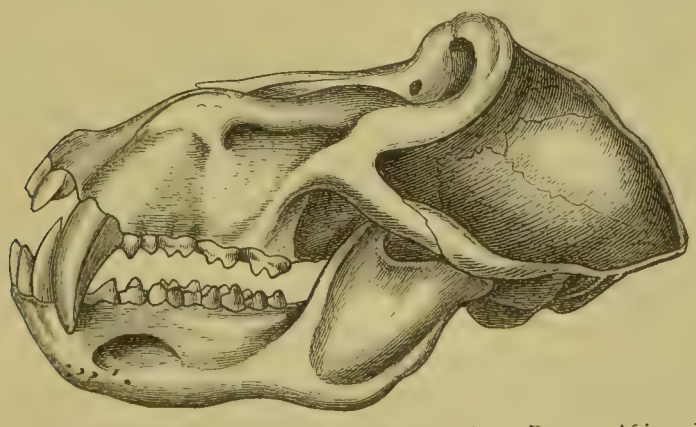


Fig. 1352.—Left lateral view of the skull of *Cynocephalus ursinus;* Recent. Africa. Reduced.

inus. The Asiatic genus *Semnopithecus* is known by remains of existing species in the Indian Pleistocene, and by extinct forms in the Siwaliks of the same country, and also in the Lower Pliocene of France and Italy. *Mesopithecus*, from the Lower Pliocene of Greece and Hungary, is an extinct genus allied in cranial characters to *Semnopithecus*, but in the structure of the limbs approximating to *Macacus*. The genus *Cynocephalus*, now confined to Africa, and characterised by the long and projecting facial region and the nearly vertical position of the orbits (fig. 1352), is found fossil in the Pliocene Siwaliks of India, and in the Pleistocene of Southern India and Algeria; and thus indicates the intimate relations of the Indian and African faunas. *Oreopithecus*, from the Middle Miocene of Italy, was probably allied to the preceding genus, but only an immature mandible is known.

Family Simiidæ.—In the *Simiidæ*, which includes the Gibbons, Orangs, Chimpanzees, and Gorillas, the tubercles of the cheek-teeth (fig. 1353) are low and blunt, and the angles of their crowns are more or less rounded off, and the third lower true molar has no hind talon. The canines are large, and the hallux is opposable. The Gibbons are represented in a fossil state in the Pleistocene of Borneo by a species of *Hylobates*, and by another from the Middle Miocene of France which may be included in the same genus, although separated by some under the name of *Pliopithecus*. *Dryopithecus*, from the Middle Miocene of France and the Lower Miocene of Hessen-Darmstadt, was a large Ape of the size of the Chimpanzee, but with teeth resembling those of the Gorilla. Lastly, the Pliocene Siwaliks of India have yielded a species of *Anthropopithecus* (*Troglodytes*) apparently closely allied to the existing African Chimpanzee; while there are also indications in the same deposits of a species of the Malayan genus *Simia* (Orang). A skull of the existing species of *Simia* is shown in woodcut, fig. 1354.



Fig. 1353.—Palatal aspect of the mandible of *Hylobates antiquus*; from the Middle Miocene of France.

Family Hominidæ.—The last and highest family of the class comprises only Man (*Homo*), and requires but little notice in this work. It may, however, be observed that the teeth form a nearly even horse-shoe-shaped series, without any diastema or marked increase in the size of the canine, and are thus in striking contrast

to those of the *Simiidæ* (compare A and B in fig. 1354); although their number and structure are identical. The skull is also remarkable for the great relative size of the cranial, and the shortness of the facial portion.

Man has certainly existed throughout the Pleistocene period, and there is also evidence of his presence at the epoch of the St Prest beds of the south of France, which are equivalent to the Norfolk Forest-bed, and are referred by some authorities to the base of the Pleistocene, and by others to the top of the Pliocene. Somewhat doubtful evidence of his existence in the true Pliocene of Italy has

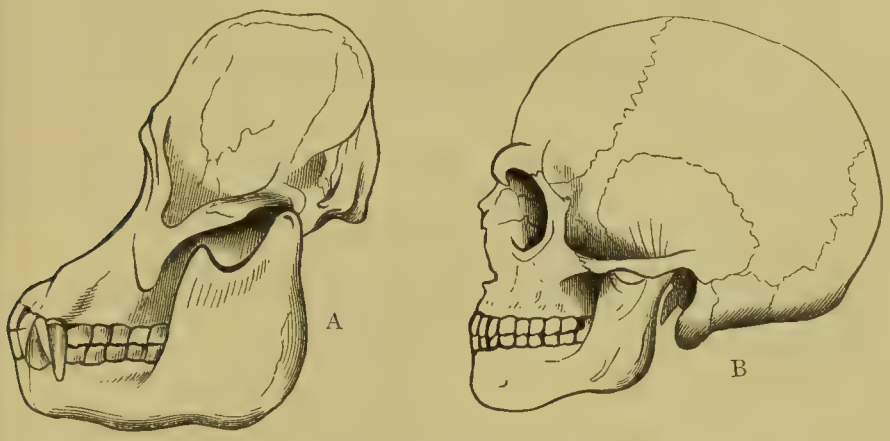


Fig. 1354.—Left lateral view of the skull of (A) the Orang (*Simia*) and (B) a European. Reduced.

been brought forward; and it has been asserted that a skull found in Calaveras county, in the United States, is from Pliocene beds. In the latter instance, however, some authorities doubt whether the skull in question was really obtained from these beds, while others consider that the beds themselves are not earlier than the Pleistocene. Far stronger proofs than those hitherto brought forward must be forthcoming before the alleged existence of Man in the Middle Miocene of France can be accepted. The evidences of his existence in the Recent period belong rather to the domain of the archæologist and ethnologist than to that of the palæontologist.

In conclusion, it may be mentioned that Professor Cope regards the *Hominidæ* as having originated independently of the other Anthropoidea from a Lemuroid stock; but much more conclusive evidence than that yet adduced is necessary to support this view.

LITERATURE OF MAMMALIA.

1. ADAMS (A. LEITH).—"British Fossil Elephants." 'Mon. Pal. Soc.' (1877-78).
2. —— "Dentition and Osteology of the Maltese Fossil Elephants." 'Trans. Zool. Soc.,' 1874.
3. BURMEISTER (H.)—"Description Physique de la Républic Argentine, &c.," vol. iii. Buenos Ayres (1879).
4. —— Various memoirs in the 'Annales del Museo Publico do Buenos Aires,' vols. i.-iii.
5. CAPELLINI (G.)—Numerous memoirs on Fossil Cetacea in Italian Serials.
6. COPE (E. D.)—"Vertebrata of the Tertiary Formations of the West," book i. 'Rep. U.S. Geol. Surv. Terrs.,' vol. iii. (1884).
7. —— "Vertebrate Palæontology of Territory West of 100th Meridian," 'Rep. U.S. Geol. Surv. W. of 100th Meridian,' vol. iv., pt. 2 (1877).
8. —— "Synopsis of the Fauna of the Puerco Series." 'Trans. Amer. Phil. Soc.,' vol. xvi. (1888).
 See also various memoirs in 'American Naturalist,' and 'Proc. of Philadelphia Academy of Nat. Science.'
9. CUVIER (G.)—"Ossemens Fossiles." 2d. ed. Paris (1821-25).
10. DAWKINS (W. B.), and SANFORD (W.)—"British Pleistocene Mammalia." 'Mon. Pal. Soc.' (1866-71).
11. DEPÉRET (C.)—"Recherches sur la Succession des Faunes de Vertèbres Miocènes de la Vallée du Rhone." 'Arch. Mus. Lyon,' vol. iv. (1886).
12. FALCONER (H.)—"Palæontological Memoirs and Notes of." Edited by C. Murchison. London (1868).
13. —— and CAUTLEY (P. T.)—"Fauna Antiqua Sivalensis." London (1846-49).
14. FILHOL (H.)—"Etude des Mammifères Fossiles de St Gérand-le-Puy, Allier." 'Ann. Sci. Géol.,' vols. x. and xi. (1879-81).
15. —— "Etude des Mammifères Fossiles de Ronzon, Haute-Loire." 'Ann. Sci. Géol.,' vol. xii. (1882).
16. —— "Recherches sur les Mammifères Fossiles du Quercy." 'Ann. Sci. Géol.,' vols. vii., viii. (1876-77).
 See also vol. xvii. of the same serial.
17. FLOWER (W. H.)—"Catalogue of Osteological Specimens in the Museum of the Royal College of Surgeons," pt. ii., Mammalia. London (1884).
18. —— "Introduction to the Osteology of the Mammalia." 3d ed. London (1885).
19. —— and DOBSON (G. E.)—"Mammalia." 'Encyclopædia Britannica.' 9th ed.
20. GERVAIS (H.), and AMEGHINO (F.)—"Les Mammifères Fossiles de l'Amerique Méridionale." Paris (1880).
21. —— (P.)—"Zoologie et Paléontologie Françaises." 2d ed. Paris (1859).
22. —— "Zoologie et Paléontologie Générales." Two series. Paris (1867-69).
23. —— and VAN BENEDEN (P. J.)—"Ostéographie des Cétacés, Vivants and Fossiles." Paris (1868-79).

24. GAUDRY (A.)—"Animaux Fossiles et Géologie de l'Attique." Paris (1862-67).
25. —— "Animaux Fossiles du Mont Léberon." Paris (1873).
26. —— "Les Enchainements du Monde Animal dans les temps géologiques : Mammifères tertiaires." Paris (1878).
27. HUXLEY (T. H.)—"Manual of the Anatomy of Vertebrated Animals." 2d ed. London (1872).
28. KOWALEVSKY (W.) — "Osteology of the *Hyopotamidæ*." 'Phil. Trans.' (1873).
29. —— "Sur l'*Anchitherium aurelianense*, et sur l'Histoire Paléontologique des Chevaux." 'Mém. Ac. Imp. St Pétersburg,' vol. xx. (1873).
30. LEIDY (J.)—"The Extinct Mammalian Fauna of Dakota and Nebraska." 'Journ. Ac. Nat. Sci. Philadphia.,' vol. vii. (1869).
31. —— "The Extinct Vertebrate Fauna of the Western Territories." 'Rep. U.S. Geol. Surv. Terrs.,' vol. i. (1873).
32. LÉMOINE (V.)—"Etude sur quelques Mammifères de petite taille de la Faune Cernaysienne des environs de Reims." 'Bull. Soc. Géol. France,' vol. xii. (1885).
33. —— Earlier memoirs on this subject in the same serial.
34. LYDEKKER (R.)—"Catalogue of the Fossil Mammalia in the British Museum," pts. i.-v. London (1885-87).
35. —— "Fossil Vertebrata of India." 'Rec. Geol. Surv. Ind.,' vol. xx. (1887).
36. —— "Indian Tertiary and Pretertiary Vertebrata." 'Palæontologia Indica—Mem. Geol. Surv. Ind.,' ser. 10, vols. i.-iv. (1875-86).
37. MAJOR (C. J. FORSYTH).—"Beiträge zur Geschicte der Fossilen Pferde, inbesondere Italiens." 'Abh. Schweiz. pal. Ges.', vols. iv.-vii. (1877-80).
38. MARSH (O. C.)—"Dinocerata, a Monograph of an Extinct Order of Gigantic Mammals." 'Rep. U.S. Geol. Surv.,' vol. x. (1884).
39. —— Various memoirs in the 'American Journal of Science' and other American serials.
40. —— "American Jurassic Mammals." 'Geol. Mag.,' 1887, pp. 241, 289.
41. MIVART (ST G.)—"On the Possibly Dual Origin of the Mammalia." 'Proc. Royal Soc.,' vol. xliii., p. 372 (1888).
42. OSBORN (H. F.)—"The Structure and Affinities of the Mesozoic Mammalia." 'Journ. Acad. Nat. Sci. Philadelphia,' vol. ix., pt. 2 (1888). "Additional Observations on the same." 'Proc. Ac. Nat. Sci. Philad.,' Oct. 1888.
43. OWEN (R.)—"Extinct Fossil Mammalia of Australia." London (1877).
44. —— "Fossil Mammalia of the British Mesozoic Formations." 'Mon. Pal. Soc.' (1871).
45. —— "History of British Fossil Mammals and Birds." London (1846).
46. —— "Odontography." London (1840-45).
47. —— "Memoir on the *Mylodon*." London (1842).
48. —— "Memoir on the *Megatherium*." London (1860).
49. —— Various memoirs in the serials of English scientific societies.
50. —— "Zoology of the Voyage of the Beagle — Fossil Mammalia." London (1840).
51. PARKER (W. K.)—"On Mammalian Descent." London (1885).
52. POULTON (E. B.)—"The True Teeth and the Horny Plates of *Orni-*

thorhynchus." 'Quart. Journ. Microscopical Science,' 1888, p. 9.

53. ROGER (O.)—"Verzeichniss der bisher bekannten fossilen Saügethiere." 'Verhandl. Mittheil. nat. Vereins Augsburg,' 1887.
54. RÜTIMEYER (L.)—"Beiträge zu einer Natürlichen Geschicte der Hirsche." 'Abh. Schweiz. pal. Ges.,' vols. vii.-x. (1880-83).
55. —— "Die Rinder der Tertiär-Epoche, &c." 'Abh. Schweiz. pal. Ges.,' vols. iv., v. (1877-78).
56. —— "Eocäne Saügethiere aus dem Gebiet des Schweizerischen Jura." 'Denschr. Schweiz. Ges. Nat.,' vol. xix. (1862).
57. —— "Weitere Beiträge zur Beurtheilung der Pferde der Quaternär-Epoche." 'Abh. Schweiz. pal. Ges.,' vol. ii. (1875).
58. SCHLOSSER (M.)—"Beiträge zur Kenntniss der Stammesgeschicte der Hufthiere, &c." 'Morphol. Jahrbuch,' vol. xii. (1886).
59. —— "Die Nager des Europäischen Tertiärs." 'Palæontographica,' vol. xxi. (1884).
60. —— "Die Affen, Lemuren, Chiropteren, Insectivoren, Creodonten, und Carnivoren des Europäischen Tertiars." 'Beiträg. z. Paléontologie Oesterr-Ungar.,' vols. vi., vii. (1887-88).
61. SCOTT (W. B.)—"On some New and Little-known Creodonts." 'Journ. Ac. Nat. Sci. Philad.,' vol. ix. (1887).
62. —— "Notes on the Osteology and Systematic Position of *Dinictis felina*, Leidy." 'Proceedings American Phil. Soc.' (1889).
63. TELLER (F.)—"Neue Anthracotherienreste aus Süd-Steiermärk und Dalmatien." 'Beiträg. z. Paléontologie Oesterr-Ungar.,' vol. iv. (1884).
64. THOMAS (O.)—"On the Dentition of *Ornithorhynchus*." 'Proceedings Royal Society,' 1889.
65. VACEK (M.)—"Ueber Österreichischen Mastodonten, &c." 'Abh. k. k. geol. Reichs.,' vol. vii. (1877).
66. VAN BENEDEN (P. J.)—Various memoirs on the Fossil Cetacea of Belgium, published in the 'Bull. Ac. R. Belgique' and the 'Ann. Mus. R. Hist. Nat. Belgique.'
67. WEITHOFER (K. A.)—"Beiträge zur Kenntniss der Fauna von Pikermi, bei Athen." 'Beiträg. z. Paléontologie Oesterr-Ungar.,' vol. v. (1888).
68. —— "Die fossilen Hyänen des Arno-thaler in Toskana." 'Denkschr. k. Akad. Wien.,' vol. lv. (1889).

It should be mentioned that neither the above nor the preceding lists of memoirs make any approach to a complete bibliography of their respective subjects. They are merely intended to indicate to the student the sources where he will most readily obtain information, and in many cases important memoirs of an early date are not mentioned, since they are quoted in those given in the lists.

PART IV.

PALÆOBOTANY

BY

H. ALLEYNE NICHOLSON AND R. LYDEKKER

PART IV.

CHAPTER LXIV.

CLASSIFICATION AND GENERAL SUCCESSION OF PLANTS IN TIME.

The department of Palæontology which deals with the relations of Plants to time is usually spoken of under the name of Palæobotany or Palæophytology, and is one of wide extent and great complexity. To render adequate justice to the vast body of knowledge which has been accumulated as to the past history of plants, an amount of space much exceeding that available in the present work would be required. Moreover, the subject is one which cannot be thoroughly dealt with except by a specialist, and which, in itself, is of less importance to the general geological student than is Palæozoology. For these reasons, nothing more will be attempted here than to give an extremely brief and entirely general sketch of the past distribution and succession of the chief types of plant-life; the extinct groups being treated with somewhat greater detail than those now in existence. In most cases, however, no description of the characteristic structures of the different groups can be given; nor is it possible to introduce so much as a sketch of the general morphology of plants. For such the student must be referred to works devoted to structural Botany, to which he must also look for the meaning of such technical terms as are here made use of.

CLASSIFICATION.

As regards the classification of Plants, the following table shows the leading groups into which the existing members of the Vegetable Kingdom are divided :—

KINGDOM VEGETABILIA.

SUB-KINGDOM A.—THALLOPHYTA.

SERIES I.—ALGÆ.

Class 1. Diatomaceæ . . .	Diatoms.
,, 2. Phycochromophycæ .	Desmids.
,, 3. Fucaceæ	Sea-weeds.
,, 4. Chlorosporeæ . .	*Siphoneæ*.
,, 5. Florideæ . . .	Red Sea-weeds, Corallines, and Nullipores.
,, 6. Characeæ . . .	Charas.

SERIES II.—FUNGI.

This series includes the Lichens (*Lichenes*) and the true Fungi, the latter being split into several divisions which need not be inserted here.

SUB-KINGDOM B.—CORMOPHYTA.

SERIES I.—BRYOPHYTA (Anogens).

Class 1. Musci	Mosses.
,, 2. Hepaticæ . . .	Liverworts.

SERIES II.—PTERIDOPHYTA (Acrogens).

Class 1. Filicaceæ.	
Order 1. Stipulatæ.	
a. Ophioglosseæ . . .	Adders'-tongues.
b. Marattiaceæ . . .	Marattia.
Order 2. Filices . . .	Ferns.
Order 3. Rhizocarpeæ . .	Rhizocarps.
Class 2. Equisetaceæ . . .	Horsetails.
Class 3. Lycopodiaceæ.	
Order 1. Isosporeæ (*Dichotomæ*).	
a. Lycopodeæ . . .	Lycopods.
b. Psiloteæ	
c. Phylloglosseæ . . .	
Order 2. Heterosporeæ (*Ligulatæ*).	
a. Selaginelleæ . . .	Club-mosses.
b. Isoëteæ	

"Cryptogams," or Non-Flowering Plants.

SERIES III.—PHANEROGAMÆ.

Class 1. Gymnospermeæ.	
Order 1. Cycadaceæ . .	Cycads.
Order 2. Coniferæ . .	Conifers.
Order 3. Gnetaceæ . .	Welwitschia.
Class 2. Angiospermeæ.	
Subclass 1. Monocotylæ (Endogens) . . .	Grasses, Palms, Lilies, &c.
,, 2. Dicotylæ (Exogens)	Rose, Buttercup, Dandelion, &c.

"Phanerogams," or Flowering Plants.

The above classification is, in the main, the one adopted by Professor Thistleton Dyer, although a less complex arrangement of the

Thallophytes has been adopted. The divisions of the Fungi, as being of no importance to palæontologists in the present state of our knowledge, have likewise been omitted; as, also, have been several of the groups of the Algæ. In older botanical systems, plants, in place of being ranged into the two primary divisions of Thallophytes and Cormophytes, were separated into "Cryptogams" and "Phanerogams," the limits of these old divisions being indicated in the margin of the above table; and it will still be sometimes convenient to employ the former term as a collective name for the non-flowering plants. Similarly, the Cryptogams were formerly divided into Thallogens, Anogens, and Acrogens; and we still very generally meet with the two latter terms (the position of which is indicated in brackets in the table) in geological works, where the expression "Age of Acrogens" has become almost classical. It is, however, very inadvisable to retain for geological purposes a classification abandoned by the more advanced botanists; and we shall therefore adopt the names Bryophytes and Pteridophytes in place of the older Anogens and Acrogens.

The Thallophytes are cellular plants not distinctly differentiated into stem and leaf; the *Algæ* being distinguished from the *Fungi* by the presence of chlorophyll. The Bryophytes, while still wholly cellular, may have distinct stems and leaves; while the Pteridophytes are partly composed of cells and partly of long tubes or vessels, and are thus fitted for the attainment of considerable dimensions. The Phanerogams are like the Pteridophytes in being vascular plants, but differ from all the preceding groups in developing flowers, which in turn produce seeds containing an embryo. The series of the Phanerogams is again divided into the Gymnosperms, with naked seeds not enclosed in fruits, and the Angiosperms, in which true fruits enclose the seeds. This latter group is further divisible into two sections, known, from the number of the seed-leaves, as Monocotyledons and Dicotyledons. In the Monocotyledons the embryo has only a single seed-leaf or cotyledon, and the stems grow from within and show no rings of growth; the name of "Endogens" applied to the group being based on this latter feature. In the Dicotyledons, on the other hand, the embryo has two seed-leaves or cotyledons; and the group is sometimes spoken of as that of the "Exogens," since the stems (as in the Gymnosperms also) grow from without, with the formation of distinct rings of growth.

General Succession of Plants in Time.

As in the Animal Kingdom, so among plants there appears to be a general correspondence between relative rank in the scale of organisation and the order of appearance in time. Thus, as Sir William

Dawson observes, "the oldest plants that we as yet certainly know are Algæ, and with these there are plants apparently with the structure of Thallophytes, but the habits of trees, which for want of a better name I may call Protogens" [Nematodendreæ]. "Plants akin to the Rhizocarps also appear very early. Next in order we find forests in which gigantic Ferns, Lycopods, and Horsetails predominate, in association with Pines. Succeeding these we have a reign of Gymnosperms; and in later formations we find the higher Phanerogams dominant. Thus there is an advance in elevation and complexity along with the advance in geological time, but connected with the remarkable fact that in earlier periods low groups attain to an elevation unexampled in later epochs, when their places are occupied with plants of higher types."[1]

The age of Algæ and Nematophytes corresponds with the earlier portion of the Palæozoic period, while Pteridophytes, with some Gymnosperms, are the dominant forms of the later Palæozoic deposits. The Mesozoic period may be termed the "Age of Gymnosperms," while the Angiosperms assume the leading place in the Tertiary. The floras of the great geological periods, however, shade gradually into one another, and no hard-and-fast lines can be drawn between them. Thus, we have already seen that Gymnosperms make their first appearance in the Upper Palæozoic rocks, these ancient types being the precursors of the characteristically Gymnospermous flora of the Mesozoic period. In a similar manner the Upper Cretaceous flora, by its great development of Angiosperms, is more nearly related to the Tertiary than to the preceding Jurassic flora. Moreover, the evolution of the flora of different regions of the earth by no means advanced *pari passu* with the evolution of the fauna—a striking example of this fact being afforded by the Lower Gondwana beds of India and the equivalent deposits of Australia, in which, reckoning from a European standpoint, we find a full-blown Mesozoic flora coexisting with a Palæozoic fauna.

Taking a brief historical retrospect of the distribution of plants in time, we have no direct evidence of the existence of vegetable life during the period represented by the Archæan rocks. There is, however, a strong probability in favour of Sir William Dawson's view that the extensive accumulations of graphite associated with the Laurentian limestones of Canada are really of the nature of metamorphosed vegetable matter, or that they have been derived in the first instance from plants. In deposits of Cambrian age most of the supposed remains of plants belong to the obscure and difficult group of fossils commonly spoken of as "Fucoids," and supposed to be referable to the Sea-weeds. So far as the "Fucoids"

[1] Some slight verbal alterations have been made in this quotation.

of the Cambrian rocks are concerned, there is every probability that we have to deal entirely with the tracks and trails of marine animals, or with impressions of a purely inorganic character. Thus, the Cambrian fossils referred to such genera as *Cruziana* and *Bilobites* are most probably the tracks of Annelides, or the filled-up burrows of Crustaceans. The fossils from the Cambrian rocks of Sweden described under the name of *Eophyton*, and at one time supposed to be the remains of land-plants, are almost certainly not of a vegetable nature. As previously pointed out (p. 209), strong evidence has been brought forward by Nathorst in favour of the view that the striated markings of *Eophyton* are really produced by the trailing of the tentacles of Jelly-fishes over the surface of soft sediment. Lastly, the so-called *Oldhamia* of the Cambrian rocks (p. 205) has been regarded as an Alga, but it may have been produced by animal agency, or it may be wholly inorganic.

From strata of Ordovician age many supposed plants have been



Fig. 1355.—*Licrophycus Ottawaensis*, a supposed "Fucoid" from the Trenton Limestone (Ordovician) of Canada. (After Billings.)

described, and the great majority of these have been referred to the *Algæ*, and have been regarded as the remains of Sea-weeds. Most

of these so-called "Fucoids" are wholly destitute of carbon, and are almost certainly not of a vegetable nature. Many of these supposed Sea-weeds—such as those referred to the genera *Palæochorda* and *Crossopodia* (the *Crossochorda* of Schimper)—present themselves as simple, often sinuous or convoluted, raised markings on the surface of muddy or arenaceous sediments. Such markings, as specially insisted on by Nathorst, always occur in demi-relief on the *under* surfaces of the beds in which they are found; and this fact would strongly support the view that they are really the *casts* of the trails of marine animals such as Worms or Molluscs, such trails presenting themselves as depressed impressions on the *upper* surfaces of the strata. Raised impressions on the under sides of the strata, but branched, are not uncommon, and upon these have been founded such genera as *Licrophycus* (fig. 1355). These curious fossils may be regarded as probably of the nature of filled-up worm-burrows, rather than as mere surface-trails.

On the other hand, some of the so-called "Fucoids" of the Ordovician, as also of the Silurian rocks, appear to be truly the

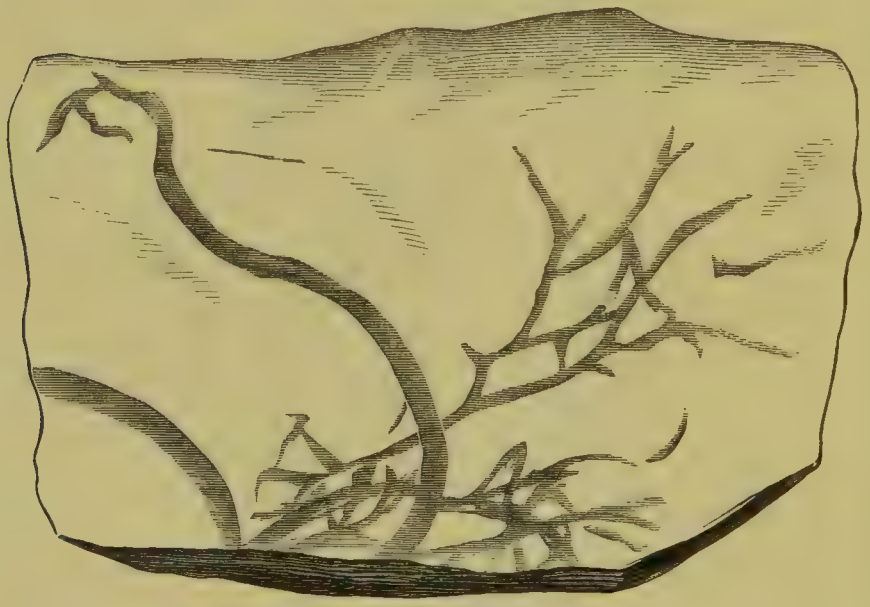


Fig. 1356.—*Buthotrephis gracilis*, Hall; a "Fucoid" from the Trenton Limestone (Ordovician) of Ottawa. (Original.)

remains of marine *Algæ*. This is the case, for example, with some of the fossils which have been referred to the genus *Buthotrephis* of Hall. The types in question (fig. 1356) present themselves as compressed, branching impressions, sometimes showing leaf-like extremities, and occasionally distinctly carbonaceous.

In addition to *Algæ*, the Ordovician rocks have yielded a few unquestionable plant-remains which are regarded by Dawson as probably having been of a higher grade. Thus, the *Protannularia* of the Arenig rocks of Britain, and the *Sphenothallus* of the Cincinnati group of North America, are provisionally referred to the Rhizocarps; while the *Protostigma* of the latter formation is looked upon as possibly allied to the Lycopods.

In the Silurian rocks we meet with various Sea-weeds of an apparently unquestionable character, and along with these are found the remains of plants of a higher type. The most abundant of these belong to the genus *Psilophyton*, regarded by Dawson as forming a connecting link between the Rhizocarps and the Lycopods. The *Glyptodendron* of the Clinton beds may perhaps be related to *Lepidodendron*, but the supposed Silurian fern, described under the name of *Eopteris*, is not truly organic. Lastly, in the Silurian rocks are found the first traces of the singular tree-like plants originally described by Dawson under the name of *Prototaxites*, but now termed *Nematophyton*. The characters of this will be briefly noted immediately; but it may be mentioned here that the curious spore-like bodies, which have been described from the Silurian rocks under the name of *Pachytheca*, are regarded by Dawson as not improbably belonging to this plant.

In the Devonian rocks, as more especially shown by Sir William Dawson, we have evidence of an abundant flora, consisting of both aquatic and terrestrial plants. Of the Devonian fossils which have been referred to the *Algæ*, the most singular is the genus *Spirophyton*, comprising certain broad, spirally twisted impressions, which are very abundant in some of the lower beds of the Devonian series of North America. Similar impressions—often spoken of under the name of "Cauda Galli"—occur in the Lower Carboniferous rocks of Europe; but their real nature is not free from doubt. We may also notice here the highly remarkable tree-like plants for which the genus *Nematophyton* (*Prototaxites*) has been proposed by Dawson, since these cannot at present be definitely referred to any recognised group of existing plants. According to Dawson, the plants in question (fig. 1357) are "trees of large size, with a coaly bark and large spreading roots, having the surface of the stem smooth or irregularly ribbed, but with a nodose or jointed appearance. Internally, they show a tissue of long, cylindrical tubes, traversed by a complex network of horizontal tubes, thinner-walled and of smaller size." The tubes appear to be arranged in concentric zones, but the plant was not truly exogenous, and it is doubtful if a genuine bark was present. The systematic place of *Nematophyton* is uncertain, but the balance of evidence would seem to be in favour of its reference to the Thallophytes, and it is regarded by Dawson as

the type of a special group, for which he has proposed the name of *Nematodendreæ*. The same authority is of opinion that the minute globular bodies to which the name of *Pachytheca* has been given,

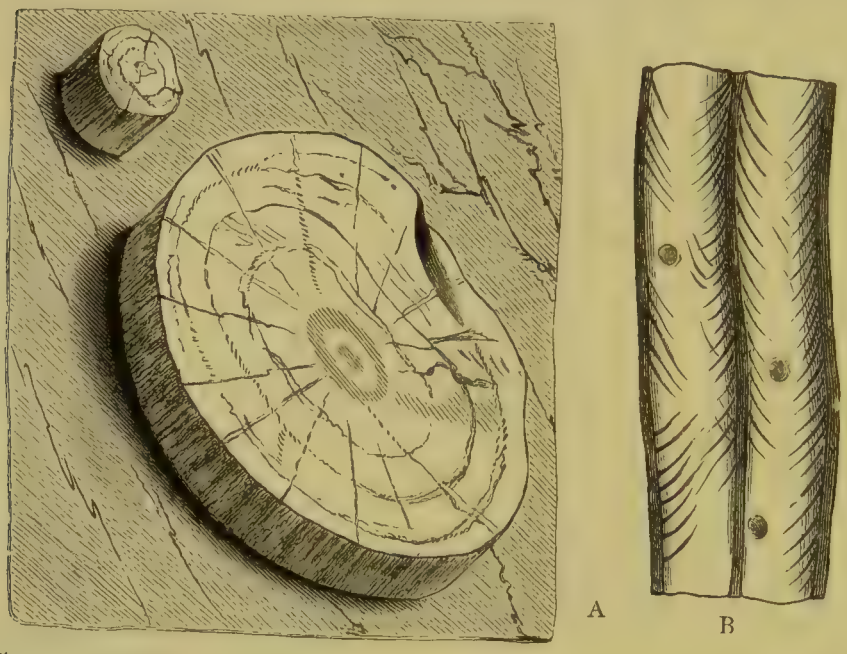


Fig. 1357.—A, Trunk of *Nematophyton* (*Prototaxites*) *Logani*, 18 inches in diameter, as seen in the cliff near L'Anse Brehaut, Gaspé; B, Two of the tubular cells forming the tissue of the stem, highly magnified. Lower Devonian, Canada. (After Dawson.)

may perhaps have been the fruit of *Nematophyton*. As previously noted, the genus occurs also in the Silurian rocks.

Coming to higher plants, the Rhizocarps are represented in the Devonian flora by such types as *Sphenophyllum* and *Psilophyton*, the latter showing affinities with the Lycopods. Moreover, some of the Devonian shales of North America are crowded with minute globular thick-walled bodies (fig. 1358), of a diameter of one-hundredth of an inch or more, which Dawson regards as being probably of the nature of the "macrospores" of plants allied to the Rhizocarps. These were originally described under the name of *Sporangites Huronensis*, but they are now referred by Dawson to the provisional genus *Protosalvinia*. Similar bodies have been shown to occur, often in vast numbers, in shales of Carboniferous age in both North America and Europe, and even some coals appear to be largely made up of structures of a similar nature.

Of still higher groups of plants, the Devonian rocks have yielded the remains of *Lepidodendron* and *Sigillaria*, representing the Lycopods, and of early types of Calamites, representing the Horsetails; while true Ferns, some of which attain considerable dimensions, are

present in comparative abundance. Lastly, the Gymnosperms are represented by the woody trunks of Conifers (*Dadoxylon*).

The Carboniferous deposits are remarkable for the richness of their contained flora, as also for the extensive development of beds of workable coal. The predominant plants of this period belong to the groups of the Pteridophytes and Gymnosperms. The former are represented by types belonging to the Rhizocarps, the Ferns, the Lycopods, and the *Equisetaceæ*; though in many cases the Carboniferous plants referred to these groups exhibit quite peculiar characters, and their precise affinities are not always clear. The Rhizocarps are represented by the ancient genus *Sphenophyllum* and by the macrospores of *Protosalvinia*. The latter sometimes occur in vast numbers in the shales of the Carboniferous period, and occasionally play an important part in the formation of coal, though this must be regarded as exceptional. The *Lycopodiaceæ* are represented by the genus *Lycopodites*, but the most remarkable members of this series in Carboniferous times are the tree-like Lepidodendroids (*Lepidodendron*, &c.) The great group of the Sigillarioids (*Sigillaria*, &c.), likewise comprising comparatively gigantic plants, is also usually regarded as belonging to the series of the Lycopods, and is highly characteristic of the Carboniferous deposits. The *Equisetaceæ*, again, are largely represented in Carboniferous times by the remarkable and widely distributed group of the Calamites. Lastly, the Carboniferous rocks have yielded the remains of a large number of true Ferns, which, in most essential respects, are similar to the existing types of the group.

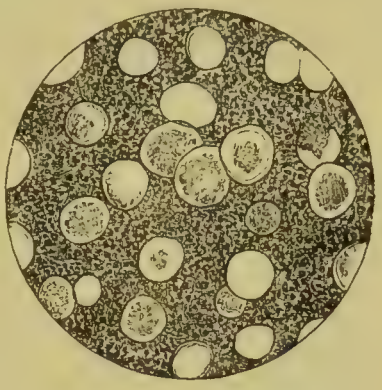


Fig. 1358.—A slice of shale from the Devonian rocks of Kettle Point, Lake Huron, showing the "macrospores" of *Protosalvinia*, magnified. (Original.)

No unquestionable Angiosperms have hitherto been detected in rocks of Carboniferous age, but the Gymnosperms are represented by various Conifers (*Dadoxylon*, *Araucarioxylon*, and *Pinites*).

It is universally admitted that coal is fossilised vegetable matter, and also that, in general, the vegetation which formed the coal grew where the coal-seam is now found. The problem of the precise mode in which the coal-seams of the Coal-measures were formed is largely a geological one, and need not be discussed here. It is sufficient to say here that coal is the result of the bituminisation of vegetable tissues of different kinds, different coal-seams, or different portions of a single seam, being often unlike in their precise structure or mode of formation. According to the researches of Sir William Dawson, the microscopic examination

of coal by means of thin sections shows that the "mineral charcoal" of an ordinary bituminous coal is woody tissue and fibres of bark. The coarser and more laminated portions of the coal are made up of "a confused mass of fragments of vegetable matter belonging to various descriptions of plants." The shining and brilliant layers of coal represent the bark of Sigillarioids or Lepidodendroids preserved in a flattened condition. Certain coals, or parts of certain coals may, further, be extensively composed of the macrospores or microspores of various Carboniferous Cryptogams; but it does not appear that coals are generally made up of such spores for any considerable portion of their mass. Lastly, the microscopical structure and chemical composition of the "cannel-coals," would show that these are "of the nature of the fine vegetable mud which accumulates in the ponds and shallow lakes of modern swamps."

The flora of the Permian period is, on the whole, nearly related to that of the Carboniferous. The Sigillarioids appear now to have become extinct, but the Lepidodendroids seem to have survived into the earlier portion of the Permian period, while the Calamites are represented by the genus *Arthropitys*, and die out at this stage. No undoubted Permian Angiosperms are known, but Conifers are tolerably abundant. Of the latter the genus *Voltzia*, which survives into the Trias, is an old type of the *Taxodineæ;* while *Walchia* connects the Yews with the Araucarias; and the genus *Ullmania* is of interest as producing true cones.

As regards the Mesozoic period, the predominant forms of plant-life in the Triassic, Jurassic, and Lower Cretaceous rocks are Cycads and Conifers; and the name of "Age of Cycads" has sometimes been given to the Mesozoic period, as regarded from a botanical point of view. Ferns, however, occur abundantly in the earlier Mesozoic deposits (Triassic and Jurassic rocks), and true *Equisetæ* make their appearance in the Upper Trias. The first unquestionable remains of Monocotyledonous Angiosperms present themselves in the Mesozoic period, the *Podocarya* and *Kaidacarpum* of the Jurassic rocks appearing to be referable to the Screw-pines (*Pandanaceæ*). True Palms do not appear till the Middle Cretaceous period is reached, but a few remains of Dicotyledonous Angiosperms have been detected in the Lower Cretaceous deposits of Greenland.

While the Lower Cretaceous rocks must be associated botanically with the Jurassic and Triassic, the Upper Cretaceous deposits, on the other hand, are characterised by a flora similar to that of the Tertiary period. From the point of view of the palæobotanist, therefore, the line of division between the Mesozoic and Kainozoic epochs falls to be drawn in the middle of the Cretaceous system. With the coming in of the Upper Cretaceous period, in both the Old and New Worlds, a remarkable change takes place in the characters of the plant-life of the land, the Cycads now assuming a position of comparative insignificance, while the Dicotyledonous Angiosperms undergo a great development and become the dominant forms.

Not only are the ordinary Exogens now the leading forms of plant-life, but many of the Upper Cretaceous types belong to genera now existing. We may therefore regard the Upper Cretaceous period as marking "the advent of the modern flora of the temperate regions of the earth" (Dawson). It follows that the Tertiary floras, regarded generally, more or less closely resemble those now in existence, this resemblance being especially shown in the fact that the predominant forms of plant-life are now the Angiosperms, and, more particularly, the Dicotyledons.

CHAPTER LXV.

ALGÆ AND FUNGI.

THE plants included in the great series of the *Thallophyta* are separable into the two primary divisions of the *Algæ* and *Fungi*, and are characterised by the fact that they are composed of cells, without true vascular tissue. They may be either unicellular or multicellular, the organism in the latter case forming an expansion or "thallus" which is not differentiated into stem, leaf, and root. In the lower Thallophytes reproduction may be wholly non-sexual; but in the higher forms sexual reproduction takes place, the result being the formation of a spore, or a group of spores, or a fructification within which spores are produced.

SERIES I. ALGÆ.—The group of the *Algæ* includes unicellular or multicellular Thallophytes in which chlorophyll is developed in larger or smaller quantity. They vary extremely in form, and are for the most part inhabitants of water, both fresh and salt. The *Algæ* may be divided into the following six classes, viz. :—

Class I.	Diatomaceæ . . .	Diatoms.
,, II.	Phycochromophycæ .	Desmids.
,, III.	Fucaceæ . . .	Brown Sea-weeds.
,, IV.	Chlorosporeæ . .	*Cymopolia*, &c.
,, V.	Florideæ . . .	Red Sea-weeds, Nullipores.
,, VI.	Characeæ . . .	*Chara* and *Nitella*.

As regards the general distribution of the *Algæ* in time, many forms are quite incapable of preservation as fossils, while others can only be preserved under specially favourable circumstances. In certain groups, however, the organism may secrete a siliceous envelope, or its tissues may undergo calcification, while others become encrusted with carbonate of lime. Such forms readily admit of petrifaction, and unquestionable remains of these occur in the fossil state. Apart from these undoubted fossil *Algæ*, numerous markings

and impressions in rocks of all ages, and especially in the older strata of the earth's crust, have been regarded by palæontologists as the remains of Sea-weeds. The characters and probable mode of origin of many of these so-called "Fucoids" have been already discussed in a general way (see p. 483 and pp. 1481, 1482). It is sufficient to say here that many of the fossils in question may be safely regarded as not belonging to the vegetable kingdom, but as being rather of the nature of the tracks and trails of Worms or Molluscs, or the burrows of Annelides or Crustaceans; while others are of purely inorganic origin. Some "Fucoids," on the other hand, such, for example, as some of the Tertiary or Secondary fossils referred to *Chondrites*, may really be the remains of Sea-weeds. Even, however, in cases where there is a reasonable probability that these so-called "Fucoids" are really Sea-weeds, it is nevertheless impossible to determine definitely to what group of the *Algæ* they belong, since the fructification of the plant is not known. In the following brief account, therefore, of the past history of the *Algæ*, only those groups will be treated of which are of palæontological importance.

Class I. Diatomaceæ.—The Diatoms are unicellular *Algæ*, in which the cell-wall is hardened by the deposition of silica so as to give rise to a glassy case or "frustule," composed of two halves which fit into one another, and which are often minutely sculptured with lines or dots (fig. 1359). The cells may be solitary, or they



Fig. 1359.—Types of Diatoms, greatly magnified. *a*, *Navicula*, from the Kieselguhr of Franzenbad; *b*, *Actinoptychus*, from Richmond, Virginia; *c*, *Pinnularia*, from Santafiora, Italy; *d*, *Achnanthes*, from Degernfors, Sweden; *e*, *Diatoma*, recent; *f*, *Triceratium*, from the guano of Saldanha Bay, Africa.

may be organically united in rows. Reproduction takes place by the longitudinal fission of the cell, each of the daughter-cells carrying off half of the original cell-wall, and producing the missing half afresh, the two halves of the siliceous case being thus of different ages.

The existing forms of the Diatoms are exceedingly numerous, and have an extraordinarily wide distribution. A few live in moist situations, but the majority are truly aquatic, inhabiting fresh, brackish, or salt waters, peculiar types usually being confined to a special habitat. By the accumulation of their flinty envelopes the Diatoms

give rise, both in the sea and in fresh waters, to very extensive deposits, the general nature of which is that of a fine siliceous mud, sometimes arranged in thin laminæ. Of this nature are the deposits known as "Kieselguhr," "Bergmehl," "Tripoli," and "Polir-schiefer," or, simply, as "Diatomaceous Earths." Such deposits may cover wide areas, and may attain a very considerable thickness; and, under an erroneous idea as to their true nature, they have been sometimes spoken of as "Infusorial Earths."

As regards their distribution in time, the cases of Diatoms have been stated to occur in the ashes of the coal of the Coal-measures, but this observation has not been supported by subsequent investigations. In the Middle and Upper Trias whole strata are sometimes largely made up of elongated, parallel-sided, siliceous tubes, with flattened sides and rounded ends, which have been described under the generic name of *Bactrynium*, and which may possibly be Diatoms. If this be their real nature, they are comparatively gigantic members of the class, as they attain a length of from two to four millimetres. Leaving these problematical fossils out of sight, undoubted Diatoms occur in the Upper Chalk, though only a few forms are known. The regular "Diatomaceous Earths" are all of Tertiary or Post-Tertiary age; and among the best known deposits of this epoch may be mentioned the numerous beds of "Kieselguhr" which occupy the sites of ancient lakes in various regions in the northern hemisphere, the "Richmond Earth" of Virginia, the "Tripoli" of Oran in Africa, and Bilin in Bohemia, and the laminated "Polir-schiefer" of Cassel.

Class II. Phycochromophycæ.—The *Algæ* included in this class are unicellular or multicellular, usually bluish-green in colour, and inhabit water or live in moist places on land. Reproduction takes place by cell-division, or by the formation of asexually-produced cells ("gonidia"). The integument is not hardened by the deposition of silica within it. In this class are included numerous widely distributed forms of the *Algæ*, such as the *Oscillariæ*, the Nostocs, and the Desmids. Owing to the soft nature of their outer covering, no undoubted remains of this class of *Algæ* have been detected in the fossil condition; but remains of *Nostoc* are said to occur in strata of Tertiary age, and the curious spherical and spined bodies which are known as *Xanthidia*, and which are sometimes recognisable under the microscope in thin sections of flint or chert, have been supposed to be the spores of Desmids.

Class III. Fucaceæ.—This class includes the common brown Sea-weeds, and comprises forms which are often of considerable size and of various shape. The thallus is often foliaceous and much branched, or may be more or less filamentous. The reproductive organs are developed in special cavities or "conceptacles." The

integument is not hardened by the deposition of lime or flint. Certain Tertiary fossils have been described by palæobotanists as belonging to this group of Sea-weeds, but the nature of many of these is very doubtful.

Class IV. Chlorosporeæ.—This class includes a number of green or olive-coloured Algæ, which live in the sea or in fresh waters, and which reproduce themselves by cell-division or by the development of spores in special cavities, while swarm-spores occasionally exist. The only group of this class which attains sufficient palæontological importance to require special notice is that of the *Siphoneæ verticillatæ*. This family includes green-coloured marine Algæ, in which the thallus consists of a single cell, which may or may not be hardened by the deposition of carbonate of lime in its wall. The single cell which constitutes the entire plant may be of gigantic size, comparatively speaking, and may be simple or branched. At its base the cell sends out root-like prolongations, by means of which it is attached to foreign bodies; while its ascending portion gives origin to whorls of lateral tubular processes. Reproduction takes place by the development of swarm-spores in special cavities or chambers. The few living forms of this family (*Cymopolia*, *Neomeris*, *Acetabularia*, &c.) are inhabitants of warm seas; and with these must be associated an extensive series of fossil types, which have been commonly regarded as referable to the *Foraminifera* or the Corals, and the real nature of which was first demonstrated by Munier-Chalmas.

As above pointed out, the thallus of the *Siphoneæ verticillatæ* may be simple or dichotomously branched, and consists of a single axial cell, which is fixed to foreign bodies by root-like basal extensions. The unicellular, often divided, axis gives out at intervals whorls of short tubular processes (fig. 1360, B), the point of origin of each whorl being commonly marked by a constriction of the stem. In some cases (*e.g.*, in *Ovulites* and *Diplopora*) the primary whorled processes do not subdivide; but in others (*e.g.*, in *Cymopolia*) the primary offshoots (fig. 1360, C, *c*) divide again into secondary processes, some of which (*b*) are sterile, while others (*a*) are connected with reproduction. The sterile offshoots terminate in free extremities which are often dilated and club-shaped, and by their apposition give rise to a porous superficial layer. The fertile offshoots, on the other hand, constitute spherical sporangia (*a*), which are wider than the sterile processes, and are at the same time supported upon shorter stalks.

In many forms, both the axis and the verticillate processes derived from it secrete a thick calcareous crust. Where the lateral whorled offshoots are simple (as in *Diplopora*), the calcareous crust has the form of a simple thickened cylinder, traversed by transverse tubes,

which correspond with the lateral processes, and open by pores upon the surface. On the other hand, where there are two orders of lateral offshoots (as in *Cymopolia*), a double calcareous cylinder is produced, the inner one corresponding with the axis and the primary whorled processes, while the outer one is formed by the confluent clavate ends of the secondary processes. The spherical sporangia may also become calcified, and may present themselves as rounded

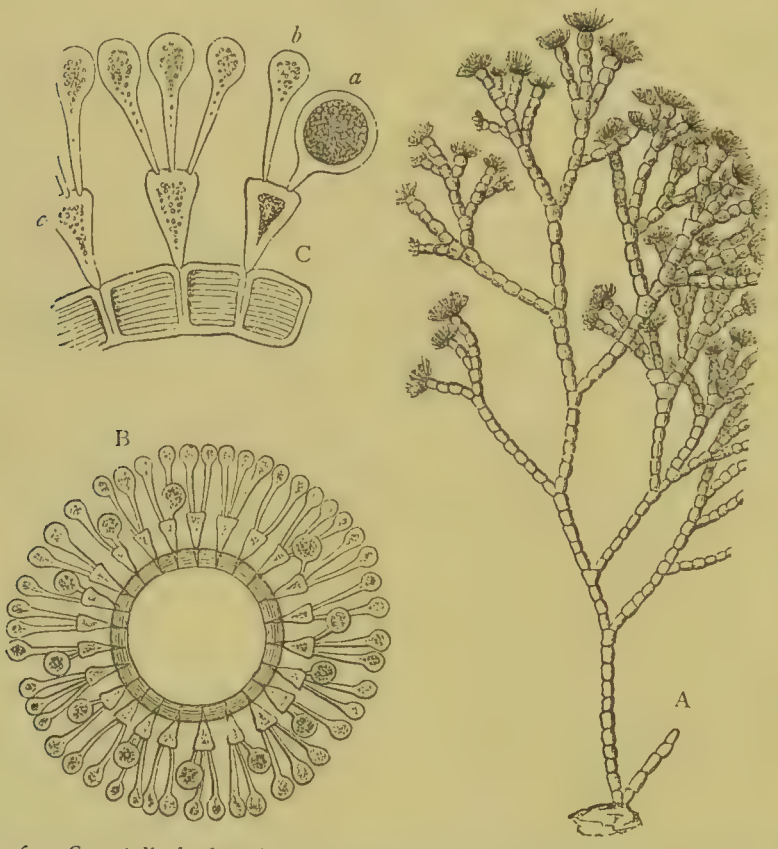


Fig. 1360.—*Cymopolia barbata* (=*C. rosarium*), from the Canary Islands (Recent). A, A specimen of the natural size, showing the divided thallus; B, Transverse section through a segment of the stem, showing a whorl of lateral processes, of which some are sterile and some fertile; C, Part of the same whorl enlarged still further, showing the primary lateral processes (*c*), giving off sterile offshoots (*b*), and spherical sporangia (*a*). (After Schimper and Zittel.)

cavities in the skeleton. Finally, the cylindrical skeleton may be composed of annular segments or may be undivided, according as the axial cell is, or is not, constricted at intervals. In the former case, the segments are often readily capable of separation, and in fossil examples often present themselves as detached calcareous rings.

When the calcareous skeleton is all that is open to our inspection, as in fossil specimens, the transverse canals with their superficial

pores, corresponding with the lateral whorled processes, may very readily be mistaken for the tubes of polypes or the chambers of polythalamous Foraminifera; and the fossil forms of the family were until recently regarded as referable to the animal kingdom. It was first shown by Munier-Chalmas ("Comptes rendus," tom. lxxxv. p. 814, 1877) that the supposed *Foraminifera* described under the names of *Dactylopora* and *Ovulites* were really referable to the *Algæ*, and that, along with many other types, they belonged to the group of the *Siphoneæ verticillatæ*. Palæontologists, in fact, are now acquainted with an extensive series of fossil forms of this remarkable family of *Algæ*, which not uncommonly give rise to very considerable rock-masses, and thus become of geological importance. The oldest type of the *Siphoneæ verticillatæ* is apparently the *Cœlotrochium* of the Middle Devonian of the Eifel; though the nature of this fossil is not absolutely certain. The Carboniferous Limestone of England also sometimes contains numbers of small calcareous cylinders, with a porous surface, which are probably referable to this family; but further investigation is needed before this can be positively asserted. It is, also, not impossible that the organism described by De Koninck from the Carboniferous Limestone of Belgium, under the name of *Monticulipora inflata* — which likewise occurs in the same formation in Britain, and sometimes attains a considerable size—may really be a peculiar type of the *Siphoneæ*. Apart from the above, the first undoubted appearance of forms of this family is in the Permian rocks, in which the genus *Gyroporella* is found. It is, however, in the Upper Trias that the maximum development of the *Siphoneæ verticillatæ* takes place, the limestones of this period being often essentially made up of the cylinders of *Gyroporella* and *Diplopora*, as occurs, for example, in the Bavarian and Tyrolese Alps. Various forms of the group also occur in the Jurassic and Cretaceous rocks, while there are numerous Tertiary types; but the family is at the present day represented by but a few species, and the range of these is very limited.

Among the more important types of the *Siphoneæ verticillatæ* which occur in the fossil state are species belonging to the genera *Cymopolia*, *Larvaria*, *Dactylopora*, *Gyroporella* (with *Diplopora*), and *Uteria*. In *Cymopolia* (fig. 1360) the thallus is branched, and is covered with a hollow calcareous crust, the surface of which shows close-set pores. The lateral processes, sterile and fertile, are developed in whorls, separated by vacant nodes. A living species of this genus is found in the seas of the Canary Islands and West Indies; while the calcareous cylinders of fossil forms occur not uncommonly in the Eocene Tertiary, and were originally described under the name of *Dactylopora*. The genus *Larvaria* is nearly allied to *Cymopolia*, and likewise includes forms—such as *L. eruca* (fig. 1361, A) and

L. annulus (fig. 1361, B)—which were originally described under the name of *Dactylopora*. Existing forms of *Larvaria* are known, and fossil types occur commonly in the Eocene Tertiary, often in the form of separate segments of the calcareous cylinder. *Dactylopora*, as now restricted, includes Eocene and Miocene types, and is also closely allied to *Cymopolia*. *Gyroporella* (including *Diplopora*) comprises types in which the skeleton has the form of a short calcareous cylinder (figs. 1361, E–G), from one to six millimetres in diameter, with two or more rows of pores on each segment of the stem. This genus begins in the Permian rocks, and is so enormously

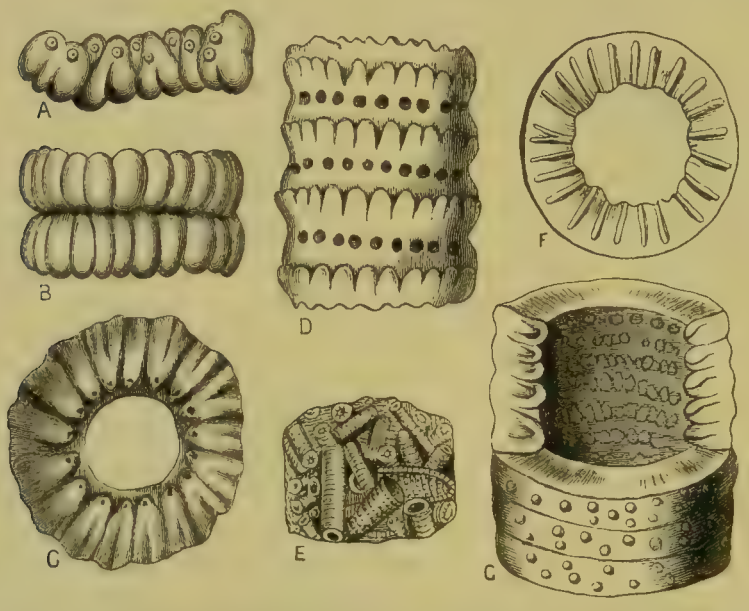


Fig. 1361.—A, *Larvaria* (*Dactylopora*) *eruca* (recent) magnified 30 diameters, and viewed from the inner face; B, *Larvaria* (*Dactylopora*) *annulus*, from the Eocene Tertiary, magnified 40 diameters, viewed in profile, and showing two superimposed rings; C, The same viewed from above and similarly magnified; D, Part of the cylinder of *Dactylopora reticulata* (Tertiary), viewed in profile, and similarly enlarged; E, Fragment of Muschelkalk, with tubes of *Gyroporella cylindrica*, of the natural size; F, Transverse section of a tube of the same, enlarged 10 diameters; G, Vertical section of the same, enlarged 12 diameters. (Figs. A–D are after Carpenter; figs. E–G are after Gümbel.)

developed in the Trias of Southern Germany and Switzerland as to give rise to massive and widespread beds of limestone. A species of this genus also occurs in great numbers in the Cretaceous series of the Southern Lebanon Mountains. In the genus *Ovulites*, again, the skeleton usually presents itself in the form of a small, ovoid or clavate, calcareous body, enclosing a single chamber, with regularly disposed superficial pores, and often perforated at both poles. Such a body is really a single joint of the stem of the original plant. The species of *Ovulites* are found in deposits of Eocene and Miocene age. Lastly, in the genus *Uteria*, the skeleton consists of branched,

cylindrical calcareous stems, which readily separate into their component segments. Each segment is hollow, with smooth or radiately-striate articulating surfaces at its ends; the inner and outer walls being porous, and the space between these being vacant. The detached segments of *Uteria* occur commonly in the Eocene deposits of the Paris basin.

Class V. Florideæ.—This class includes a large number of marine and a few freshwater *Algæ*, which are in general red or violet in colour. The thallus is very variable in form, and is often much branched. Reproduction may be sexual or non-sexual. In the former case fertilisation is effected by means of non-motile antherozoöids, the result being the conversion of the female organ into a receptacle, or "cystocarp," within which spores are formed. Non-sexual reproduction is effected by means of special cells ("tetraspores") developed in parts of the thallus.

With regard to their *distribution in time*, a few types of the ordinary Red Sea-weeds (*Delesseria*, *Sphærococcites*, &c.) have been recognised as occurring in the older Tertiary deposits. With these limited exceptions, all the fossil forms of this class belong to the Corallines and Nullipores (*Corallineæ*), in which the thallus is hardened by the deposition of carbonate of lime. The principal genera of the family of the Corallines are *Corallina*, *Melobesia*, and *Lithothamnion*.

In *Corallina*, the thallus is erect and branched, and is composed of rounded or wedge-shaped calcareous segments, which readily separate from one another. The fructification consists of "cystocarps," which are immersed and have an aperture at their summit. The "Corallines" are exceedingly abundant in existing seas, but little is certainly known of their occurrence in the fossil condition. They are, however, stated to occur in the Eocene beds of the Paris basin.

In *Melobesia* the calcareous thallus is crust-like and foliaceous, and is attached by the whole of its lower surface to foreign bodies. The superficial layer of the stony crust is composed of minute cubical cells, but the deeper cells are elongated. The "cystocarps" are immersed within the thallus, and project above the surface as wart-like tubercles. *Melobesia* has not been clearly recognised in the fossil state, though it is not improbable that it will ultimately be found to occur even in the Palæozoic rocks.

In connection with *Melobesia* a few words may be said about the curious little calcareous bodies known as "coccoliths," since it has been suggested by Carter that these are connected with the reproduction of Algæ belonging to this genus. Coccoliths are excessively minute calcareous bodies, of a discoidal form, which are found in the mud of the deep sea at the present day, often in great numbers. Similar bodies

occur abundantly in the White Chalk, and Gümbel has shown that they are present in many limestones, even in those of the older Palæozoic formations. Two distinct forms of coccoliths are known, which have been described by Huxley under the names of "discoliths" and "cyatholiths." The former of these (fig. 1362, *a*) are minute calcareous discs, averaging $\frac{1}{4000}$ to $\frac{1}{5000}$ inch in diameter, provided with a raised rim on one side (*b* and *c*), and having a central corpuscle or nucleus. The

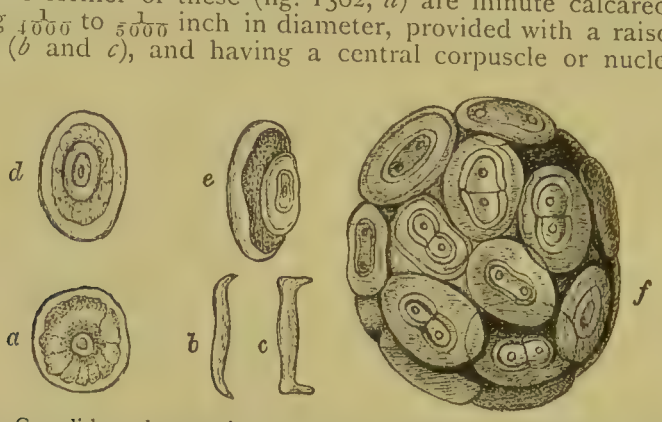


Fig. 1362.—Coccoliths and coccosphere. *a*, A "discolith" seen in front view; *b* and *c*, "Discoliths" viewed edgeways; *d*, "Cyatholith" seen in front view, showing the outer transparent zone, the inner granular zone, and the central corpuscle; *e*, "Cyatholith" seen in profile; *f*, A "coccosphere." All the figures are greatly magnified. (After W. B. Carpenter and Wyville Thomson.)

"cyatholiths" vary from $\frac{1}{1000}$ to $\frac{1}{8000}$ inch in diameter, and when viewed sideways (fig. 1362, *e*) are seen to have the form of a shirt-stud, and to consist of two concavo-convex calcareous discs, of which one is smaller than the other and is united to the concavity of the larger by a short stalk. When viewed in front (*d*), the cyatholith presents itself as an oval or circular body, composed of two concentric zones surrounding an oval central corpuscle, the inner of the two zones being more or less distinctly granular, while the outer one is transparent. Cyatholiths occur in vast numbers in the mud of the deep sea in their detached condition, but they are also found aggregated into spherical masses, which may reach $\frac{1}{700}$ inch in diameter, and are known as "coccospheres" (fig. 1362, *f*). The precise nature of the coccoliths and coccospheres is at present uncertain; but it has been suggested by Carter that the "coccospheres" are connected with the reproduction of species of *Melobesia*.

The only remaining genus of the *Corallineæ* which demands consideration is *Lithothamnion*, under which are included the well-

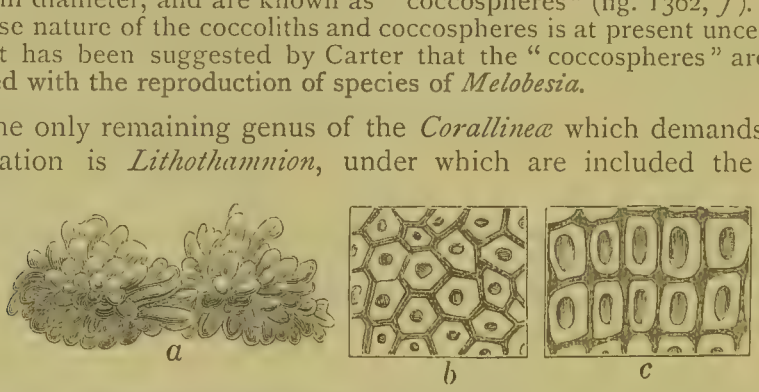


Fig. 1363.—*Lithothamnion ramosissimum*, a "Nullipore," from the "Leitha-Kalk" of the Vienna basin. *a*, Portion of a mass, of the natural size; *b* and *c*, Transverse and vertical sections of the same magnified 320 diameters. (After Gümbel.)

known and widely distributed calcareous *Algæ* which are commonly spoken of as "Nullipores," and which are exclusively marine in

habit. The thallus of the Nullipores is highly calcareous and of stony hardness, and it may be encrusting, botryoidal, stalactitic, or bushy in form (fig. 1363). As regards the microscopic structure of the calcified thallus, the outer layer is formed of hexagonal or quadrate cells of very small size, while the cells of the interior are oblong in shape. The fructification consists of "cystocarps," scattered through the thallus, and either immersed or projecting as tubercles.

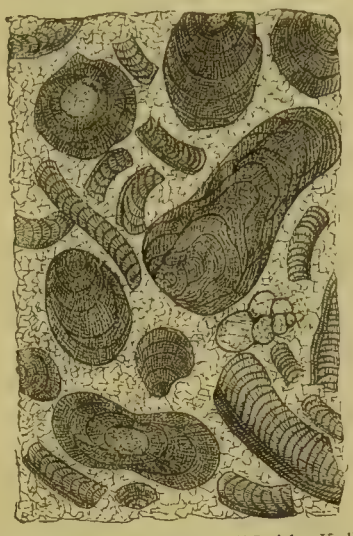


Fig. 1364.—Section of "Leitha-Kalk" (Tertiary) from the neighbourhood of Vienna, showing fragments of Nullipores (*Lithothamnion*), enlarged three times. (Original.)

As regards the distribution of the genus in time, the remains of species of *Lithothamnion* are found in vast numbers in various Tertiary formations, often giving rise to massive limestones, such as the "Leitha-Kalk" of Austria (fig. 1364), the "Nullipore-limestone" of Algeria, and others. Remains of *Lithothamnion* are also found in the Cretaceous and Jurassic rocks, and they have been said to occur in rocks as old as the Carboniferous Limestone. The fossil forms of *Lithothamnion* do not exhibit any marked structural differences as compared with the existing types of the genus.

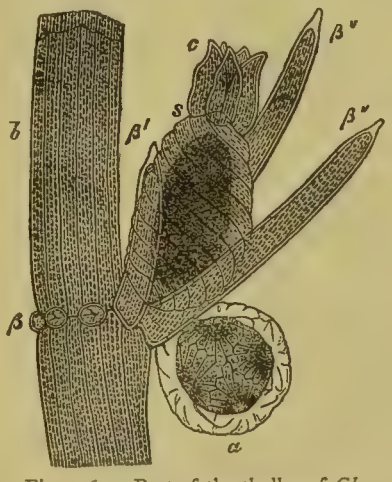


Fig. 1365.—Part of the thallus of *Chara fragilis* (Recent), showing the reproductive organs, enlarged. *b*, Central portion of a leaf with an antheridium (*a*) and a carpogonium (*s*); *c*, Crown of cells at the apex of the carpogonium; β, Sterile leaflets; β′, Large lateral leaflet near the fruit; β″, β‴, Leaflets attached to the base of the carpogonium. (After Sachs.)

Class VI. Characeæ. — This class comprises a number of freshwater or brackish-water Algæ, of a green colour, and remarkable for having lateral appendages corresponding with leaves. The thallus consists of a central stem giving off whorls of leaves at intervals, which in turn give off secondary leaflets. The male reproductive organ has the form of a spherical sac (fig. 1365, *a*), and has been sometimes spoken of as the "globule." The female reproductive organ or "carpogonium"—sometimes spoken of as the "nucule"

—consists of a large central cell surrounded by a sheath of spirally-twisted cells, and bearing a crown of small teeth at its summit (fig. 1365, *s*).

The recent genus *Nitella* remains permanently soft, and is unknown in the fossil condition. On the other hand, the integument of *Chara* itself becomes hardened by an encrustation of carbonate of lime, and is thus capable of preservation in the fossil state. The fossil forms of the genus *Chara* occur in the Triassic, Jurassic, and Cretaceous formations, and are abundant in parts of the Tertiary series. In some cases (as in the chert of the Purbeck beds) the stems are found; but the fruits or "carpogonia" are more commonly preserved. These have the form of spirally ridged or grooved, ovoid or globular bodies (fig. 1366), and the first type discovered was described by Lamarck under the name of "Gyrogonites." The fossil carpogonia of species of *Chara* are abundantly found in certain freshwater deposits, both of Secondary and of Tertiary age.



Fig. 1366.—*a*, Carpogonium of *Chara Gressini*, Tertiary, enlarged; *b*, Carpogonium of *Chara Medicaginula* ("Gyrogonites"), from the Eocene beds of the Paris basin, enlarged. (After Schimper and Zittel.)

Fungi.

The series of the *Fungi*, in which the Lichens are now included, comprises Thallophytes which are closely allied to the *Algæ*, but which are devoid of chlorophyll. Owing to the soft nature of their



Fig. 1367.—A, A lenticular specimen of *Archagaricon*, of the natural size; B, Slice of the same showing the tubes and vesicles, enlarged. Coal-measures. (After Hancock and Atthey.)

tissues, the *Fungi* can only be preserved in the fossil state under specially favourable conditions. The plants of this series are, therefore, of very small palæontological importance, and may be very briefly dismissed.

Various minute forms of *Fungi* have been recognised as occurring on the leaves of fossil plants, the oldest of these being found on the leaves of Cycads in Triassic deposits. The fossil leaves of Tertiary plants are very commonly attacked by these parasitic plants; and other minute forms have been detected in amber. In other cases, the mycelial tubes of a Fungus have been preserved within the woody stem of a plant of higher grade, or the entire Fungus may have undergone silicification. Thus, the mycelial tubes of a Fungus (*Peronosporites*) have been detected in the tissues of the stems of Carboniferous plants. Messrs Hancock and Atthey have also described, under the name of *Archagaricon*, certain silicified fossils from the Coal-measures of Northumberland, which they regard as referable to the *Fungi*. These remarkable fossils (fig. 1367) present themselves as oval, rounded, lenticular, or irregular bodies, under an inch in length, which appear on microscopic examination to be composed of irregular, ramifying, tubular filaments, terminating in rounded vesicles.

Lichens are almost unknown as fossils, no example of these plants having been detected in any Palæozoic or Mesozoic deposit. A few forms have, however, been recognised in amber, and others have been detected on the bark of fossil trees in lignites of Tertiary age.

CHAPTER LXVI.

SUB-KINGDOM CORMOPHYTA.

Series Bryophyta and Pteridophyta.

Sub-Kingdom B. Cormophyta. — This division, which includes all other plants, can only be distinguished as a whole from the Thallophyta by the general presence of leaves, stem, and root; or at least by the opposition of the stem and root. The alternation of generations is more regular than in the Thallophytes; a sexual production of sporophores, and an asexual production of oöphores, following in sequence.

Series I. Bryophyta.—The first series includes the Mosses and Liverworts, which are cellular plants, with complete alternation of generations, and without true vascular tissue. The spores, either directly, or by the intervention of a *protonema*, give rise to the sexual generation, or *oöphore*, which forms the main plant, in the female organ (*archegonium*) of which arises the *sporogonium* (*sporophore*) from which the spores are asexually produced. The main plant is therefore a sexual oöphore.

Class 1. Musci.—In the Mosses the spore produces a large conferva-like protonema, from which the plant (oöphore) arises by lateral branching, and is differentiated into stems and leaves upon which the sexual organs are formed. The class is practically of no palæontological importance, and it will accordingly be unnecessary to notice its divisions. All the fossil forms at present known are of Tertiary age; but from the occurrence of a Jurassic Beetle allied to types which live in moss, it is inferred that the class is really much older. A number of species have been found in amber, most of which appear allied to existing European types; and some also occur in the Miocene of Bonn and the Upper Eocene of Provence, but the absence of fructification renders their generic position uncertain. The genus *Sphagnum*, or Peat-moss, has, however, been definitely determined from the Miocene of Westerwald.

Class 2. Hepaticæ.—The Liverworts differ from the Mosses in the absence of true leaves, and in the bilateral condition of the plant, which has the side exposed to the light differently organised from the concealed one; the oöphore, moreover, generally arises directly from the spore, the protonema, when present, being insignificant. Hair-like growths, representing aborted leaves, are occasionally present on the under side of the plant; and it is fairly certain that Liverworts are to be regarded as degraded forms which have lost the leaves and branches of the Musci. The widely spread existing genus *Marchantia* is represented in the European Eocene and Miocene, and numerous *Jungermanniaceæ* have been found in amber; but beyond this nothing is known of the palæontological history of the class.

Series II. Pteridophyta.—The Pteridophytes are characterised by the great vegetative development of the sporophore, and the tendency to the suppression of that of the oöphore, or sexual generation. Their tissue develops fibro-vascular bundles, and there is a distinct epidermis. There is also a complete alternation of generations, the spore developing a sexual *prothallium* (oöphore), from the archegonium, or female organ, of which is sexually produced the main plant or sporophore, which in its turn asexually develops spores of one or two kinds in organs termed *sporangia*; the latter being generally borne either on ordinary or specialised leaves, but in some cases on the stem. It will be apparent from this that the main plant is an asexual sporophore corresponding physiologically with the sporogonium of the Bryophytes, while the sexual prothallium represents the leaf-bearing plant of the latter.

The Pteridophytes—equivalent to the Acrogens of older writers—are of extreme importance to the palæontologist, since they contain several groups of entirely extinct types; and in the earlier epoch of the earth's history, when they were not brought into extensive competition with the Phanerogams, they attained an importance, both in the number of types and in the large size attained by many of their representatives, which entitles them to be considered the dominant forms of the Palæozoic epoch.

Class I. Filicaceæ.—The Ferns and their allies have the leaves highly developed, and frequently much branched in a pinnate manner; the sporangia being numerous, and borne either upon the ordinary or specially modified leaves, on which they are usually arranged in groups or *sori*. The class may be divided into three orders.

The leaves of Filicaceæ may be either simple, as in *Glossopteris* (fig. 1376), or pinnate. Among pinnate types the pinnation may be simple, as in *Neuropteridium* (fig. 1373), when the leaflets or pinnules are arranged upon a single shaft; or bipinnate (*Neuropteris*, fig. 1371), when

secondary shafts are developed; tripinnate, as in *Sphenopteris* (fig. 1369), when tertiary shafts occur; or multipinnate. The coverings of the sori are termed *indusia;* and when the stem is creeping it is known as a *rhizome.*

Order 1. Stipulatæ.—This order now contains only the two families *Ophioglossaceæ* and *Marattiaceæ*, characterised by the presence of stipules at the base of the petioles of the leaves. Of the former *Ophioglossum* (Adder's-tongue), in which the sporangia are embedded in the tissue of the partly sterile and partly fertile leaves, occurs in the Middle Eocene of Monte Bolca; while it is probable that *Chiropteris*, of the Keuper of Würtemberg, is not really separable. In the second family, where the sporangia are external, as in the Ferns, the existing genus *Marattia* occurs in the Rhætic and Lias of the Continent. *Danæites* and *Danæopsis*, on the other hand, are extinct types, the former occurring in the Cretaceous of Europe, and the latter in the Keuper, and probably also in the Permian, of the Tyrol, as well as in the Rajmahal stage of the Indian Gondwanas. Finally, the living genus *Danæa* occurs in the Lias of Verona. Several of the fossil forms have been confused with the *Tæniopterideæ*, while Schimper has referred to this family some of the forms noticed under the *Pecopterideæ*. According to Mr Kidston, the *Archæopterideæ* should probably be placed in this order.

Order 2. Filices.—In existing Ferns stipules are wanting; and there is only one kind of spores; so that the sexual stage is not reached till the prothallium.

Existing forms are classified by the nature of their fructification; but since this is generally unknown in the earlier fossil types, we are compelled to classify them by the nature of the pinnation and venation of the leaves, and as these are subject to great variation among allied existing genera, it is evident that this classification is more or less of an artificial nature. It will be convenient to follow Schimper's plan of treating first of those existing families which are known to be represented in a fossil state, and then to notice the forms of which the position is more or less uncertain, but which are provisionally arranged in families.

Existing Families.—In the existing series the family *Osmundaceæ* has the paniculate fructification borne on specialised leaves, which may or may not be like the sterile ones. The type genus *Osmunda*, which is mainly characteristic of warmer regions, although represented in England by the Royal-Fern, occurs fossil in the Cretaceous of Westphalia and Greenland, in the Laramie beds of North America, and in many of the European Tertiaries. An allied form, from the freshwater deposits of Chemnitz, has been named *Asteroclæna.* In the *Schizeaceæ*, which usually have the fructification borne in spikes or panicles on the *laciniæ* of the

leaves, the existing tropical genus *Lygodium* occurs in Europe from the Cretaceous to the Miocene, and also in the Laramie beds of the United States. The third family—*Gleicheniaceæ*—has the sessile sporangia borne in naked sori upon the dorsal surface of ordinary leaves, each sporangium having a complete transverse ring, and bursting with a longitudinal slit; while the stem forms a creeping rhizome. The existing tropical genus *Gleichenia* is represented by closely allied forms in the Cretaceous of Greenland, the Rajmahal group of the Indian Gondwanas, and in the Lias of Verona, some of which have been separated as *Gleichenites*. *Didymosorus*, from the Cretaceous of Greenland and Saxony, with two sori on each leaflet, connects the preceding with *Mertensia*. The latter, which has two rows of sori on each leaflet, and is now confined to the southern hemisphere, occurs in the Cretaceous of Greenland and Hungary. The *Hymenophyllaceæ*, or Film-ferns, in which the sessile sori are covered by an indusium, are represented by one species in the Upper Eocene of Provence; while Schimper has referred to the type genus *Hymenophyllum* a Carboniferous fern. It is probable that some of the *Sphenopterideæ* are more or less closely related to this family. The fifth family—*Cyathecaceæ*—which includes the tropical Tree-ferns, is of more palæontological importance; it is characterised by the stalked sporangia, situated in closely packed sori, which may be naked or covered. Of Tree-ferns, in which there is a tall stem, often covered with roots, and crowned with a rosette of leaves, the existing *Alsophila* is represented in the Lower Eocene of Sézanne, which also contains other allied forms. The Carboniferous *Choroniopteris* should perhaps find a place here. Of smaller forms, the genus *Onoclea* (in which Schimper includes *Struthiopteris*) is represented in the Laramie Cretaceous and the Miocene of the United States, as well as in the Eocene of the Isle of Mull, by the existing *O. sensibilis* of North America; thus offering a remarkable instance of the persistence of a specific type. The Mull form was originally described as *Filicites*. The Laramie series also yields an extinct species of this genus. These ferns, like the following, have the sporangia borne on specialised leaves. *Dicksonia*, which is mainly tropical and often tree-like, occurs in the European Keuper, and more abundantly in the Jurassic, and is also found in the Indian Rajmahal beds. Finally, *Thrysopteris*, now known only by a single species from Juan Fernandez, is also very common in the European and Siberian Jurassic (fig. 1368), where it has been described as *Coniopteris* and *Tympanophora*. In addition to the special fertile leaves, a few sori are borne at the base of the ordinary leaves, as shown in the figure.

Lastly, we come to the extensive family *Polypodiaceæ*, which includes the greater number of European ferns, and is divided

into several subfamilies. The sporangia are very numerous, and are borne on the underside of usually unmodified leaves; and they split transversely. Of the subfamilies, the *Polypodieæ* are perhaps represented by the typical *Polypodium* in the Miocene of Switzerland; *Chilanthes* occurs in the same deposits; while the widely-spread *Pteris* (Bracken) is found abundantly in the Upper Cretaceous and the Middle and Upper Tertiaries of Europe, and also in the Laramie and Tertiaries of America. *Adiantum* is also equally well represented throughout the European Tertiaries, and if we include in it the so-called *Adiantites*, it ranged down to the Jurassic. In the *Asplenieæ*, *Blechnum* (Hard-fern), distinguished by having both fertile and sterile leaves, of which the latter are simply pinnate, occurs in the Continental Eocene and Miocene. Curiously enough, the South American genus *Hewardia* is found in the Upper Eocene of Bournmouth. *Woodwardia*, now represented by eight species from the warmer regions of the world, occurs in the Pliocene and Miocene of Europe, the species from the former, and perhaps also that from the latter, horizon being identical with an existing type; this genus also occurs in the Miocene of the United States. *Asplenium*, which at the present day numbers some 300 species, occurs commonly throughout the European Tertiaries, and is also found in the Cretaceous; some of the species being allied to existing European forms, while others are more nearly related to those of the tropics. It appears, moreover, that Ferns from the Jurassic of Siberia and the Jurassic and Rhætic of Europe, described under the name of *Cladophlebis* and *Alethopteris*, are referable to this genus. Ferns of this genus also occur in the English Wealden; in both the Lower (Damuda) and Upper (Raj-

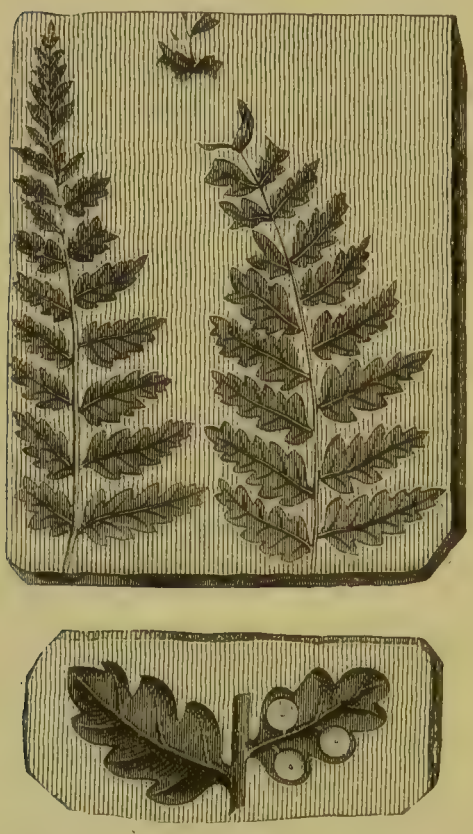


Fig. 1368. — Lateral branches of the leaves of *Thrysopteris Murrayana*; from the Inferior Oolite of Yorkshire. Enlarged leaflets, with sori, are shown in the lower figure.

mahal) Gondwanas of India; and in certain New Zealand beds, correlated by Baron von Ettingshausen with the Trias. In the last subfamily, or the *Aspidieæ*, the cosmopolitan *Aspidium* and the allied *Lastræa* occur commonly from the Middle Tertiaries upwards.

Fossil Families.—An enormous number of Palæozoic and Mesozoic Ferns belong to this series, but only a few of the more important types can be even mentioned. The *Sphenopterideæ* comprise a number of Ferns, mostly of very delicate structure, and extremely difficult to classify. They are usually multipinnate, with the pinnæ in some cases dichotomous; at least the terminal leaflets are narrowed at the base; while all are often lobate, and with the veins dividing in a pinnate or forked manner from the base. The fructification of some forms has been described by Mr Kidston, and it is suggested that one or more of the genera may be allied to the existing *Hymenophyllaceæ*. Many of the species have exceedingly delicate fronds. Among the Carboniferous genera may be mentioned *Sphenopteris* (fig. 1369), *Calymmatotheca*, *Zeilleria*, *Urnatopteris*, in which there are fertile and sterile leaves, *Oligocarpia*, *Renaultia*, *Rhachopteris*, *Sphenopteridium*, and *Eremopteris* (fig. 1370). Of these, the first ranges from the Devonian to the Lower Jurassic of Europe, and is also found throughout a large part of the Indian Gondwanas, in the African Karoo system, in the Australian Hawkesbury beds, in New Zealand, and the Palæozoic of the United States.[1] *Eremopteris* also occurs in the Indian Gondwanas, and ranges in Europe to the Permian; and a Fern from the Kimeridgian of France has been named *Stenopteris*.



Fig. 1369.—Part of a leaf of *Sphenopteris trifoliata*; from the European Carboniferous. (After Schimper.)

The family *Archæopterideæ* (*Palæopterideæ*) was placed by Schimper in the present serial position; but the recent observations of Mr Kidston upon the type genus appear to indicate that it should be transferred to the Stipulatæ—although, until the necessity for such transference be absolutely proved, it appears preferable to leave the family in its old position. The leaves are bipinnate, and both these and the leaflets are usually stalked; the leaflets being broad and often lobate. The type genus *Archæopteris*, which has

[1] Ferns from the Laramie beds and American Tertiaries have been referred to this genus.

also been generally known by the preoccupied name of *Palæopteris*, occurs in the Devonian and Carboniferous of both Europe and the United States. According to Mr Kidston, it has stipules on the leaves, and its fructification appears to consist of sporangia devoid of annuli, and closely resembling those of the *Marattiaceæ*. The genus *Aneimeites*, from the Devonian of Canada, has been placed by Sir J. W. Dawson and Mr Kidston in the same family; which is



Fig. 1370.—*Eremopteris artemisiæfolia*; from the Carboniferous.

also taken to include *Triphyllopteris*, from the European Carboniferous. The latter genus has both fertile and sterile leaves.

With the important family of the *Neuropterideæ* we return to the consideration of true Filices. In this group the leaves vary from a simple to a tripinnate type; the leaflets being either long or ovoid, and often narrowed at the base, with the midrib disappearing towards the extremity, and the veins equal, and in typical forms rising at an acute angle. The genus *Neuropteris* (fig. 1371) is a bipinnate type very common in the Carboniferous, but also extending into the Permian of Europe. The allied *Cyclopteris* (which is not admitted by Mr Kidston as a distinct genus) extends in Europe from the

Carboniferous to the Rhætic, and is also found in the upper part of the Lower Gondwanas of India (fig. 1372). The leaf has sub-

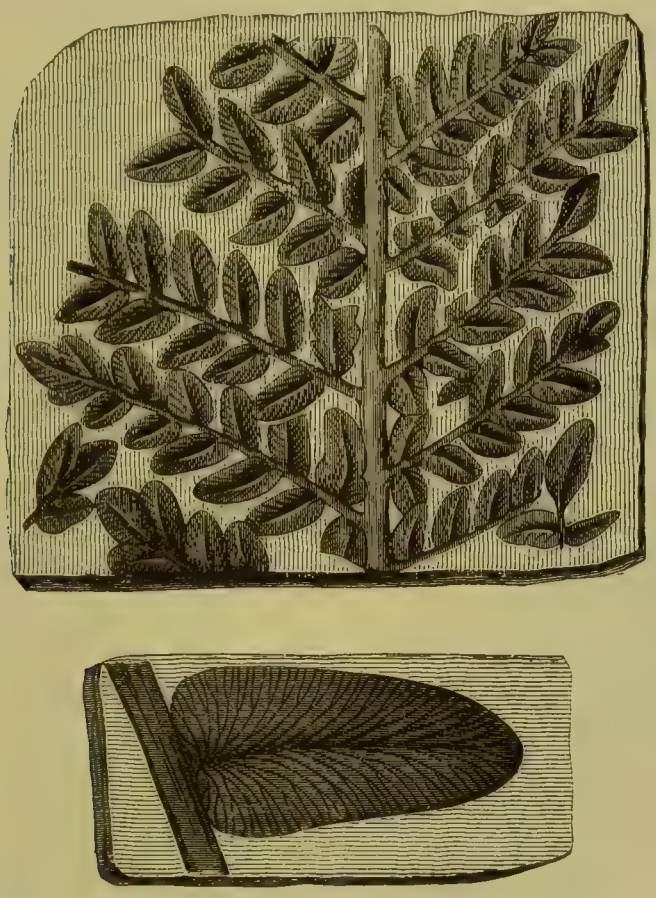


Fig. 1371.—*Neuropteris heterophylla*; from the Coal-measures of Europe. The lower figure shows a single leaflet enlarged.

orbicular leaflets resembling those of the existing Maiden-hair fern, with no midrib, and the veins numerous and dichotomising as they radiate to the margin. The typical Carboniferous forms, according to Mr Seward, have pinnate leaves, but in the figured Rhætic form referred by Dr Feistmantel to this genus they are bipinnate. *Neuropteridium* (fig. 1373) is a simply pinnate form occurring in the Lower Trias of Europe, and in the base of the Lower Gondwanas. *Dictyopteris* includes



Fig. 1372.—Part of leaf of *Cyclopteris pachyrhachis*; from the Panchet stage of the Lower Gondwanas of India. (After Feistmantel.)

Carboniferous ferns with a net-like venation as in *Glossopteris* (fig. 1376). Finally, Mr Kidston includes in this family the simply pinnate *Cardiopteris*, of the Lower Carboniferous, in which the somewhat heart-shaped leaves are devoid of a midrib. The *Odontopterideæ* form a well-defined family with bi- or tripinnate leaves, in which the leaflets are attached by the whole width of their base; the leaflets are non-lobate, with their veins proceeding wholly from the base, or in part from an indistinct midrib. The type genus

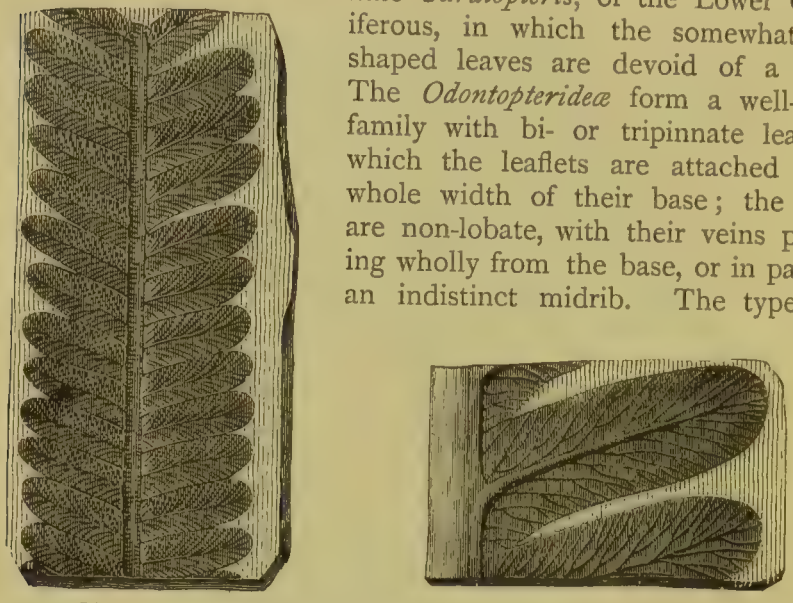


Fig. 1373.—Part of leaf of *Neuropteridium elegans*, and two leaflets enlarged; from the European Trias.

Odontopteris (fig. 1374) occurs in the Carboniferous and Permian, the figured species being common to Europe and North America.

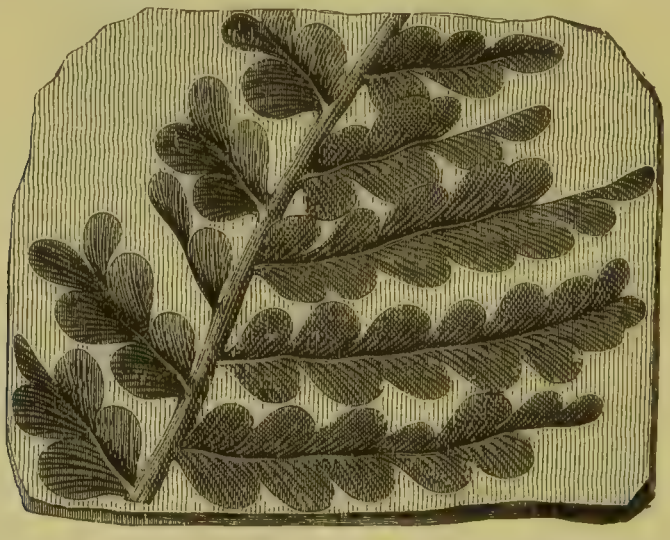


Fig. 1374.—Part of leaf of *Odontopteris osmundæformis*; from the Carboniferous of Europe.

The bipinnate *Ctenopteris* (fig. 1375), from the Rhætic and Lower Lias, has leaves curiously resembling those of the Cycadaceous

Bowenia. The *Alethopterideæ* are multi-pinnate ferns with a strong general resemblance to the existing *Pteris*, and at least some of which have a similar marginal fructification. The leaflets are attached by their whole base, the bases of adjacent leaflets being united; and the midrib is complete. *Alethopteris*, of the Carboniferous and Permian, is common to Europe and the United States; the Mesozoic forms described under this name having been noticed under the head of *Asplenium*. *Lonchopteris*, of the Carboniferous, is distinguished by its net venation; while we have another type in the Permian *Callipteris*. Another multi-pinnate type is constituted by the *Pecopterideæ*, which agree with the last family in the attachment of the leaflets, with the exception that the adjacent bases are usually distinct; the midrib, although slender, continues to the extremity; and the veins arise less obliquely than in the *Neuropterideæ*. The typical *Pecopteris*

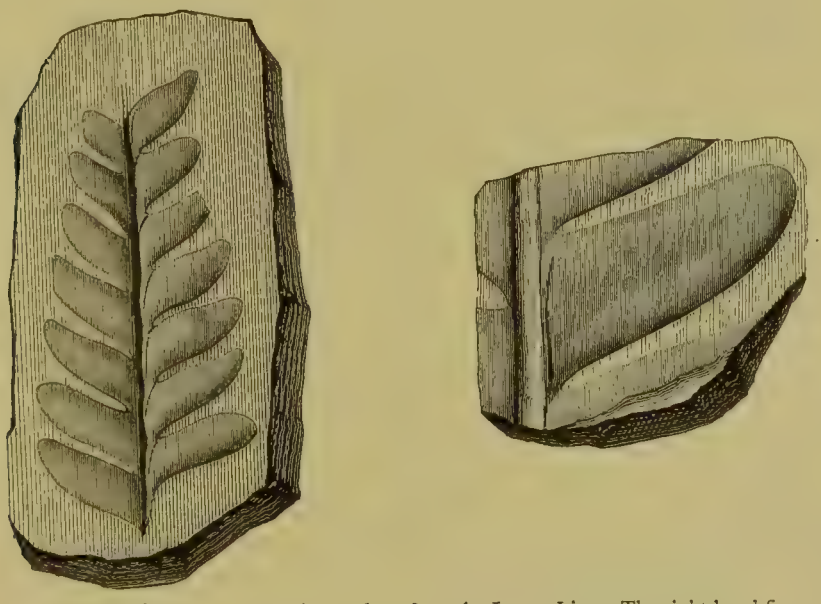


Fig 1375.—A pinna of *Ctenopteris cycadea*; from the Lower Lias. The right-hand figure shows an enlarged pinnule or leaflet.

contains a very large number of species, some of which are tree-like, from the Devonian and Carboniferous of both Europe and North America; and many of which have been referred to the *Marattiaceæ* under the names of *Asterotheca*, *Stichopteris*, &c., but which Mr Kidston considers to be generically inseparable. It also occurs in the Trias of Europe, and in Lower Mesozoic beds in New Zealand. Other Carboniferous genera are *Mariopteris*, *Callipteridium*, and *Dactylotheca*. In the Mesozoic we have also a large number of

forms which may be provisionally placed here, although it is probable that at least a moiety belong to existing families. One series has been named on the evidence of sterile, and the other on that of fertile leaves, and there is accordingly a considerable probability that different genera have been named from a single species. Of the former series a fern from the Keuper and the Panchet series of the Indian Gondwanas has been described as *Pecopteris concinna;* and we also have *Lepidopteris* from the Rhætic, *Merianopteris* from the Keuper and the Damuda series of the Gondwanas, *Anomopteris* of the Keuper, and *Crematopteris* of the Bunter. In the second series, where the leaves consists of palmate branches on a long stalk, we have *Lacopteris*, *Matonidium*, *Marzaria*, *Andriana*, &c. The *Pachypterideæ* are Mesozoic ferns, with small leaves, and include the Liassic *Dichopteris*, and the Oolitic *Scleropteris* and *Stachypteris;* *Pachypteris* itself being a doubtful form probably based upon remains of two of the preceding genera. The fructification of some of these Ferns resembles that of the existing tropical Polypodiaceous genus *Onychium*, to which they may be allied. In the present family Dr Feistmantel would include *Thinnfeldia*, a peculiar genus having thick leaves, which may be only simply pinnate, with lobate pinnæ; and occurring typically in the Rhætic and Lower Lias, but also found in the Indian Panchets, in the reputed Trias of New Zealand, in the Hawkesbury and overlying beds of Australia, and also in Argentina. The *Lomatopterideæ* include a few Mesozoic ferns of allied types, having thick fleshy leaves, which are usually simply pinnate, with lobation of the pinnæ. Exclusive of the last-named genus this family contains *Lomatopteris*, extending from the Bath Oolite to the Kimeridgian and probably the Wealden; and *Cycadopteris*, which ranges from the Lias to the Upper Jurassic.

With the *Tæniopterideæ* we come to a family easily recognisable by their usually simple strap-like leaves (fig. 1376), with a well-developed midrib, which are curiously like those of the Plaintain (*Musa*). It may be divided into two subfamilies, according to the venation. In the first subfamily, with a normal venation, *Tæniopteris* is represented by a few European and North American Carboniferous species, and also occurs in the Trias of Europe and New Zealand. The allied *Macrotæniopteris* comprises some very large ferns, ranging in Europe from the Keuper to the Lower Lias, and doubtfully to the Inferior Oolite, while it occurs in India in both the Upper

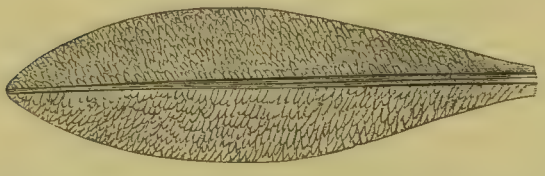


Fig. 1376.—Leaf of *Glossopteris retifera;* from the Lower Gondwanas of India. Reduced. (After Feistmantel.)

and Lower Gondwanas, and is also found in New Zealand and Australia. *Palæovittaria* seems peculiar to the Damuda series of the Lower Gondwanas. *Oleandridium* has stalked leaves differing somewhat in their venation from the preceding, and is considered to be allied to the existing *Oleandra* among the *Aspidieæ;* it occurs in the European Mesozoic and the Panchets. *Angiopteridium* and *Marattiopsis* are distinguished by a simple pinnation of the leaves; the former occurring in the Damuda series of the Gondwanas, and the latter in the European Carboniferous. The genus *Glossopteris* (fig. 1376) is the only representative of the second subfamily, and is distinguished by its net-like venation, retaining, however, the well-marked midrib characteristic of the family. It is extremely abundant in the Indian Gondwanas, ranging from the Talchir to the Upper Jurassic Jabalpur stage, and is also met with in the Hawkesbury beds of Australia, in the upper part of the African Karoo system, in the Cretaceous of Russia, and in beds of unknown age in Italy. Finally, the *Gangamopterideæ*[1] include Ferns with a net venation, in which the leaves are subject to great variation in shape, but may be digitate or fan-like, and devoid of midrib. There is one division with simple, and another with compound venation. In the former we have *Gangamopteris*, ranging throughout the Lower Gondwanas and also found in the Bacchus-Marsh beds of Victoria; and *Belemnopteris* of the *Damudas;* both being probably allied to the *Polypodiaceæ.* In the second group *Camptopteris* occurs in the Keuper; *Dictyophyllum* ranges from the Rhætic of Germany to the Cretaceous of Greenland; while *Clathropteris* is confined to the Rhætic, and *Protorhipis* to the Lias.

Fern-stems.—Omitting a few fossil Ferns of uncertain affinities, brief reference must be made to a few types of large size described upon the evidence of portions of the stem, but which cannot at present be definitely classed. Of these *Megaphyton*, from the Carboniferous of Europe and the United States, is founded on trunks of Tree-ferns, which bore their large leaves in a row on either side of the stem, and which Sir J. W. Dawson considers very unlike any existing type. *Psaronius*—a type common to the Old and New Worlds, and mainly of Devonian age—is founded on trunks of Tree-ferns marked by alternate leaf-scars, which are usually surrounded by aerial roots like those of many existing forms. *Caulopteris*, which is likewise found in both Europe and North America, is characterised by its vertically elongated leaf-scars. It ranges from the Carboniferous to the Permian; but at least some of the forms described under the name of *Ptychopteris*, which extends upwards to the Trias, are not generically separable. *Protopteris*, of the Cretaceous of Europe and Greenland, is another large form,

[1] Usually termed *Dictyopteridæ*, but not including *Dictyopteris* (p. 1507).

characterised by the bases of the leaf-stalks remaining attached to the scars, as in many recent Tree-ferns. Other forms are *Cyatheopteris* of the Bunter, and *Thamnopteris* ranging from the Permian to the Keuper; the latter having persistent leaf-stalks. Finally, *Rhizomopteris* of the Carboniferous, and *Sphallopteris* of the Bunter, are based on specimens generally regarded as rhizomes of large creeping ferns. The genus *Palæopteris*, from the Carboniferous, which was long considered to be a fern, is named from a specimen which appears to be the stem of one of the *Cordaiteæ*.

Order 3. Rhizocarpeæ. — The Rhizocarps are distinguished from the Ferns by the development of two kinds of spores termed *macrospores* and *microspores*. Their young shoots may be either straight, or circinate as in Ferns and *Psilophyton* (fig. 1378).

Although the macrospores and microspores are true spores, as developing plants without fertilisation, yet they may be regarded as incipient sexual elements, and thus throwing back the sexual differentiation to an early stage. Thus the microspores, or male elements, develop only male prothallia, which produce antheridea; while the macrospores, or female elements, develop female prothallia, which produce only archegonia.

The four existing genera of this order are aquatic plants, which may be simply floating, or may have a creeping rhizome. Of the *Salviniaceæ* the rootless genus *Salvinia* is represented in the Upper and Lower Miocene of the Continent, and also in the Laramie and higher beds of America. Of the two existing genera *Pilularia* (Pillworts) and *Marsilia*, constituting the family *Marsiliaceæ*, it is probable that a species of the former occurs in the Upper Miocene of Œningen, while *Marsilia* is recorded from the Miocene of Oregon in the United States, and also from the Lower Miocene of Ronzon near Puy-en-Velay. It has been suggested that *Sagenopteris*, ranging in Europe from the Rhætic to the Lower Jurassic, and also occurring, together with the allied *Dactylopteris*, in the Damudas of India, may be more or less closely allied to the *Marsiliaceæ*. They are plants of considerable size, with long-stalked leaves terminating in a palmate expansion of four or more members. *Marsilidium*, of the Wealden, has also been referred to the same family.

Sir J. W. Dawson considers that in the early Palæozoic the characters afterwards separated in the Club-mosses, Horse-tails, and Ferns were united in the Rhizocarps, and it will accordingly be convenient in this place to notice certain Palæozoic plants apparently more or less closely allied to the Rhizocarps, some of which should probably be included in the same order, while others may be intermediate types connecting that order with the Equisetaceæ and Lycopodiaceæ. In the first place, as previously noted (p. 1484), certain spherical bodies known as *Sporangites* occurring

in the Devonian and Carboniferous of North America and Europe, are regarded by Sir J. W. Dawson as macrospores or sporocarps of Rhizocarps, under the name of *Protosalvinia*. Better known is the genus *Sphenophyllum* (fig. 1377), likewise occurring on both sides of the Atlantic, and ranging from the Ordovician to the Carboniferous, which many authorities now agree in provisionally placing in this order, although others would refer it to the Equisetaceæ. They were small plants with wedge-shaped leaves arranged in regular whorls, after the manner of the existing *Marsilia*. Another type which is regarded by Dr Feistmantel as closely allied to the preceding is *Trizygia*, known by a single species from the Lower Gondwanas of India. These plants (if complete) are comparatively small, with a slender stem bearing incomplete whorls of wedge-shaped leaves; each whorl occupying only three sides of the stem, and consisting of six leaves arranged in three dissimilar pairs. They were probably aquatic.



Fig. 1377.—Leaf of *Sphenophyllum antiquum*; from the Devonian of Canada. Enlarged and natural size. (After Dawson)

Here also, according to Sir J. W. Dawson, should be placed the genus *Ptilophyton* (fig. 1378), which appears to be most nearly

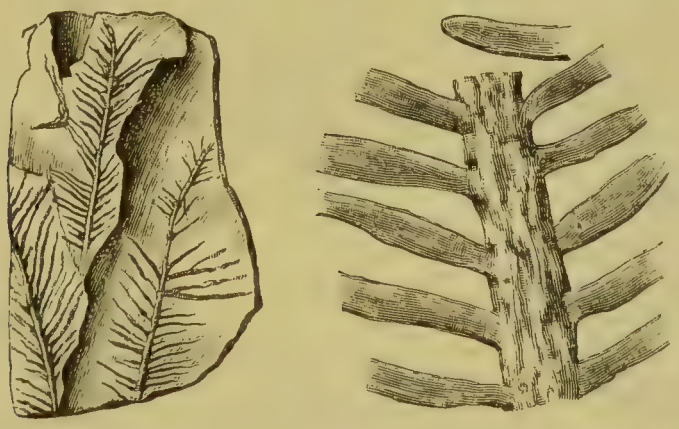


Fig. 1378.—*Ptilophyton plumosum*: from the Lower Carboniferous of Nova Scotia. The right-hand figure shows a portion magnified. (After Dawson.)

allied to the Rhizocarps. The genus ranges in North America from the Middle Devonian to the Lower Carboniferous, and is also found in the Old Red Sandstone of Scotland. These organisms, which have been referred to the Algæ and Lycopodiaceæ, are composed of feather-like leaves, apparently bearing macrospores on parts of the stem or petioles. They are considered to have been of aquatic

habits, the linear pinnæ of the leaves acting as floats. Finally, there remains for consideration the imperfectly-known plants from the Ordovician (Arenig beds) of England to which the hybrid name *Protannularia* has been given; and which were originally referred to the Thallophytous genus *Buthotrephis*. They consist of slender branching stems bearing at intervals whorls of linear leaves (fig. 1379), somewhat resembling those of the Equisetaceæ, to which class they may be more or less closely allied.

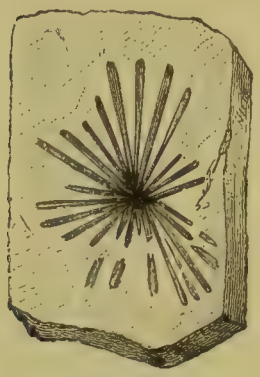


Fig. 1379. — A leaf-whorl of *Protannularia Harknessi*; from the Ordovician of the North of England.

Class II. Equisetaceæ. — With this group we come to a small class now represented by only a single genus with species of comparatively small size, but which in the Palæozoic contained numerous forms of large dimensions, and occupying an important position in the contemporary vegetation. The class may be briefly characterised by the rudimentary condition of the leaves, which are reduced to small sheathing whorls, borne either on the stem or on branchlets also arising in whorls from the joints of the barren stem. The sporangia, which produce only one kind of spores, are borne upon specially modified leaves forming a terminal spike to the main stem (fig. 1381, A), there being distinct fertile and barren stems.



Fig. 1380. — *Schizoneura gondwanensis*; from the Damuda series of India. Much reduced. (After Feistmantel.)

The existing family *Equiseteæ* comprises small forms, characterised by their perennial rhizome, from which the annual stems arise. The single existing genus *Equisetum* (Horse-tails) occurs in most parts of the world, with the exception of Australasia; and seems to have commenced in the Lower Keuper, where species of much larger size than their existing analogues are met with; and from this period representatives occur throughout most of the European Mesozoic and Tertiary strata and also in some of those of North America, and in the Lower Mesozoic of New Zealand. The Carboniferous *Equisetites* seems to have been an allied genus.

The extinct family *Schizoneureæ* is typically represented by the genus *Schizoneura* (fig. 1380), which occurs throughout the European Trias, and perhaps also in the Jurassic, and in the Lower Gondwanas of India. According to Dr Feistmantel, these plants are characterised by the

sheaths found at the joints of the stalks, which in an early stage of development consist of a number of leaflets, with median veins, and attached by their margins. In the course of development these sheaths split either into thin component leaflets, or more frequently into two equal and opposite portions (as in the figure), which thus simulate paired leaves. The stems and stalks are longitudinally ribbed. *Phyllotheca*, which occurs in Europe from the Lias to the Lower Jurassic, in the Lower Gondwanas of India, and the Newcastle beds of Australia, seems to be more nearly allied to *Equisetum*, but is placed by Schimper in this family. The joints of the stem are of moderate length, and the outer surface is fluted; while the leaves are linear, and free at their extremities, but at the base are united in a sheathing whorl, which may be longer than the joints of the stem. Each leaf has a midrib.

With the *Calamiteæ* we come to another extinct family, which is confined to the Palæozoic, and contains the largest representatives



Fig. 1381.—Restoration of *Calamites*, greatly reduced. A, *C. Suckowii*; B, *C. Cistii*. (After Dawson.)



Fig. 1382.—Leaves and branchlets of *Calamites ramosus* (*Asterophyllites foliosa*); from the Carboniferous of England. Reduced. (After Lindley and Hutton.)

of the class, some of the species probably attaining a height of about 30 feet. Their stems are tall and cylindrical, with a hollow pith-cavity divided into sections by diaphragms, and bearing at the joints either whorls of needle-like leaves (fig. 1381, B), or branchlets carrying secondary whorls of leaves (fig. 1381, A). In transverse section these stems show radiating bundles of fibres,

resembling those of Conifers, and showing great variation of structure in the different forms. The base of the stem generally terminates in a blunt point (fig. 1384), and it may be attached to the rhizome, or several stems may spring from a common stock, as in the restoration figured. The roots are cylindrical, and may be branching. There has been great confusion in regard to the determination of Calamites owing to the difficulty of referring fruits, leaves, and roots to their respective stems; and also owing to the fact that while in some cases the entire stem is preserved, in others only a cast of the pith-cavity remains. According to Mr Kidston the well-defined genera based on stems are *Calamites*, ranging from the Carboniferous to the Permian; *Calamocladus* and *Asterocalamites*, of the Devonian and Carboniferous; and *Arthropitys*, of the Permian. At least some of the specimens to which the names *Annularia* and *Asterophyllites* (fig. 1382) have been applied are branchlets of *Calamites*. Fruits of *Asterocalamites* have been described as *Pothocites*; while others known as *Stachannularia* have been found attached to the branchlets of *Annularia*. Other fruits described as *Volkmannia*, *Calamostachys*, and *Macrostachya* are probably likewise referable in many instances to *Calamiteæ*, although it has been suggested that some may belong to *Sphenophyllum*. Roots known as *Pinnularia* have been found attached to *Calamites*, but some of the specimens to which this name has been applied may belong to other plants. There has been considerable discussion as to the nature of the outer surface of the bark of *Calamites*, but it appears from the most recent observations that in species with thin bark this surface was fluted, while in those with thick bark it was smooth.



Fig. 1383.—Part of stem of *Calamites cannæformis*; from the Carboniferous of Europe. Reduced.

A large number of synonyms in addition to those already mentioned have been made; among which it may be observed that Mr Kidston includes *Asterophyllum*, or *Asterophyllites*, and *Archæocalamites* in *Asterocalamites;* while *Calamodendron* is regarded as inseparable from the type genus. *Calamiteæ* occur both in Europe and North America, but are unknown in India and Australia.



Fig. 1384.—Lower extremity of stem of *Calamites cannæformis;* from the European Carboniferous. Reduced.

According to Sir J. W. Dawson, "it would seem, from the manner in which dense brakes of these Calamites have been preserved in the coal-formation of Nova Scotia, that they spread over low swampy flats, and formed fringes on the seaward side of the great Sigillaria forest. In this way they no doubt contributed to prevent the invasion of the areas of coal accumulation by the muddy waters of inundations, and thus, though they may not have furnished much of the material of coal, they no doubt contributed to its purity."

Here may be noticed the remarkable jointed stem-like bodies known as *Vertebraria*, which are generally regarded as Equisetaceous, and occur throughout the Lower Gondwanas of India, and are also found in the Newcastle beds of Australia. These peculiar bodies, which are often branched, and may be of considerable size, are regarded as the rhizomes of an Equisetaceous plant of which the foliage is unknown. Their association in India with *Schizoneura* is noteworthy.

Class III. Lycopodiaceæ.—The third and last class of the Pteridophytes, known as Lycopodiaceæ or Dichotomeæ, is now represented by the Club-mosses and Selaginellas, and also includes a number of allied extinct types of much larger dimensions. These plants are characterised by a simple or branched stem, without joints, usually having roots, and bearing numerous small and simple leaves; while the branches of the stem and frequently of the roots divide dichotomously (fig. 1387). The sporangia are solitary, and borne either upon the upper surface of the base of the leaves, or in the axils of the latter, or simply upon the stem. The class may be divided into two orders.

Order 1. Isosporeæ.—The Club-mosses, which are the existing representatives of this order, are characterised by producing only one kind of spores, and by the absence of *ligulæ*, or membranes at the base of the leaves, as well as by certain other points which need no mention here.

The earliest plant referred to this order is *Psilophyton*, which is

regarded by Sir J. W. Dawson as forming a connecting link between the Rhizocarps and the Lycopods, and probably forms the type of a distinct family, the *Psilophyteæ*. This genus, with which *Haliserites* is identical, occurs in the Lower Devonian of both Europe and the United States, and is a plant of more than average interest. It attains considerable dimensions, and has minute or rudimental leaves, which are numerous and spirally arranged on the barren stems, but are sparse or absent on the fertile ones. On decorticated stems their point of attachment is represented by minute scars. The young branches have circinate terminations (fig. 1385), like the "crosiers" of Ferns; while the rhizomes are circular, and show irregularly placed areolæ, to which the roots were attached. The inner structure of the stem consists of an axis of scalariform tissue, surrounded by cells. Finally, the fructification (fig. 1386) consists of naked oval sporangia, generally borne in pairs on lateral or terminal pedicels, which are regarded by Sir J. W. Dawson as making the nearest approach to the sporocarps of the Rhizocarps. *Arthrostigma*, from the Devonian of Canada, is placed by the same authority in this family.

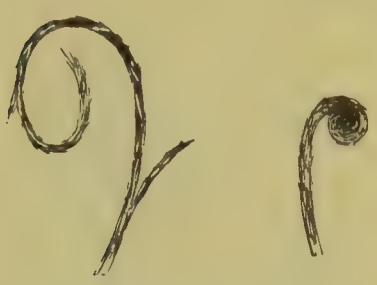


Fig. 1385.—Circinate terminations of young branches of *Psilophyton princeps*. (After Dawson.)

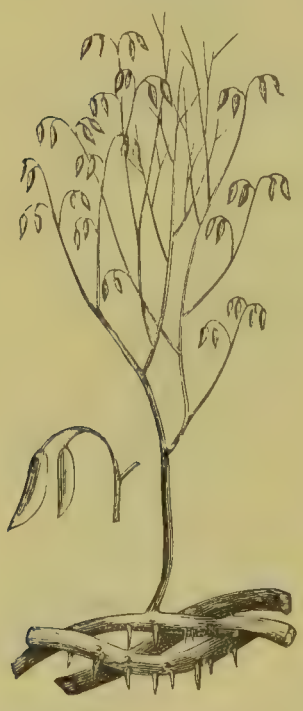


Fig. 1386.—Reduced restoration of *Psilophyton princeps*; from the Lower Devonian of Canada. (After Dawson.)

The three existing families of the order—viz., *Lycopodieæ*, *Psiloteæ*, and *Phylloglosseæ*—are of but little palæontological importance; the last two being unknown in a fossil condition. *Lycopodium* occurs in the Jurassic; while in the Permian, Carboniferous, and Upper Devonian there occur allied forms for which the name *Lycopodites* has been proposed. The Devonian *L. Milleri* is, however, a *Psilophyton*. *Lycopodites* also occurs in Lower Mesozoic beds in New Zealand.

Order 2. Heterosporeæ (Ligulatæ).—This order, now represented by *Selaginella* and *Isoëtes*, is distinguished by developing two kinds of spores—viz., macrospores and microspores—and by the presence of ligulæ to the leaves. In both the prothallium is developed within the

macrospore; thus almost suppressing the first or sexual generation. The family *Selaginelleæ* includes only the living genus *Selaginella*, which is mainly characteristic of the warmer regions, and especially of the southern hemisphere. The stem is flattened, with two



Fig. 1387.—*Lepidodendron Sternbergi*; from the Carboniferous. The left-hand figure shows a cone, and the right the extremity of a branch.

opposite rows of leaves, which are often of a glaucous hue, and the fruit is in the form of long spikes, arising from the axils of the leaves. It is considered probable that this genus is represented in the Coal-measures of the Continent by species which have been

referred to *Lycopodites*, and it undoubtedly occurs in the Laramie series of North America.

With the *Lepidodendreæ* we come to the first of the two extinct families of the order, which contains gigantic forms characteristic of the Upper Devonian and Carboniferous. These were tree-like Lycopods with linear single-veined leaves, which leave rhomboidal scars, often very prominent, at their point of attachment to the dichotomously-branching stems. The fruit is in the form of scaly cones, bearing macrospores and microspores, which may be either terminal or lateral; and the young branches have a pith-cavity, surrounded by a layer of scalariform tissue, which sends out processes through the thick bark to the leaves. As is the case with so many Palæozoic types, the different portions of these trees have received distinct generic names. Thus the decorticated stems have been named *Knorria*, fruiting branches, *Halonia*, and cones (fig. 1388) *Lepidostrobus*, while at least some of the roots known as *Stigmaria* (fig. 1392) are referable to the present family. According to Sir J. W. Dawson, there is considerable difference in the mode of growth of the outer surface in different members of the family.

"Thus in some species the areoles, at first close together, become, in the process of the expansion of the stem, separated by intervening spaces of bark in a perfectly regular manner; so that in old stems, while widely separated, they still retain their arrangement, while in young stems they are quite close to one another. This is the case in *Lepidodendron corrugatum*. In other species the leaf-scars or bases increase in size in the old stems, still retaining their form and their continuity to one another, as in *L. undulatum*, and those forms which have large leaf-bases. In these species the continued vitality of the bark is shown by the occasional production of lateral strobiles [cones] on large branches, in the manner of the modern Red-pine of America. In other species the areoles neither increase in size nor become regularly separated by growth of the intervening bark; but in old stems the bark splits into deep furrows, between which may be seen portions still retaining the areoles in their original dimensions and arrangement."



Fig. 1388.—Cone of a Lepidodendroid Tree (*Lepidostrobus Dabadianus*); from the Carboniferous. One-third natural size. (After Schimper.)

The majority of the genera are common to Europe and the United States, and some of them occur in other parts of the world, as in the Palæozoic of Australia, and the *infra*-Karoo series of South Africa. The type genus *Lepidodendron* contains a number of species with a most complex synonomy, and is characterised by its vertically elongated leaf-scars and slender branches. According to the views of Mr Kidston, the stems to which the name *Ulodendron* has been applied are mainly referable to *Lepidodendron*, although others may

be Sigillarian; Sir W. Dawson has, however, identified *Ulodendron* with the next genus. *Lepidophlœus* (*Lomatophlœus*), which appears to be exclusively Carboniferous, has the leaf-scars transversely elongated, with three vascular points, and placed on distinct prominences; while the branches are thick, the leaves very long, and the cones always lateral. *Hallonia* is founded on fruiting branches of this genus; while fruits of one type of the so-called *Lepidostrobus* (fig. 1388) have been found attached to stems with the scars of *Lepidophlœus*. *Cyclostigma* and *Leptophlœum* are exclusively Devonian; the former being characterised by the circular or horse-shoe-like leaf-scars, and the latter by the flat and rhombic leaf-bases and obsolete scars. *Leptophlœum* occurs in the United States and Australia.

The existing genus *Isoëtes*, the sole representative of the *Isoëteæ*, is known in a fossil condition by two species from the Miocene of the Continent, and by a third from the Eocene of Colorado.

With regard to the serial position of the second great Palæozoic family of the *Sigillareæ*, there has been much discussion, but the general consensus of opinion seems now to be in favour of placing them in the present order; although it is quite probable that, as Sir J. W. Dawson suggests, at least some of them may be more or less closely allied to the primitive Gymnosperms. Their resemblance to the *Lepidodendreæ* is indicated by their strongly-marked external similarity; which is especially shown in the tall, slender, and dichotomously-branching stem (fig. 1389), the slender grass-like leaves, the leaf-scars arranged in whorls, and the Stigmarian roots. These trees, constituting the genus *Sigillaria*, are mainly of Carboniferous age, and are common to the Old and New Worlds; they attained very large dimensions, their stems being sometimes as much as five feet in diameter. Not unfrequently these stems are found in an erect position (fig. 1390), passing through several layers of rock; while in other cases they have been found attached to the Stigmarian roots which penetrate the clays underlying the seams of workable coal. The columnar



Fig. 1389.—A, Reduced restoration of *Sigillaria Browni*; B, Do. of *S. tessellata*; from the Carboniferous. (After Dawson.)

stems of the Sigillarians are marked by continuous longitudinal ribs, between which are the leaf-scars (fig. 1391), forming whorls round the stems. It will be seen from the figure that the arrangement of these scars is such that each one is placed in the interval between two scars of the horizontal rows immediately above and below; this arrangement, or *phyllotaxis*, obtaining in all plants with leaves forming whorls. The external coat of the stem is very hard, beneath which is an inner bark composed of cellular tissue traversed by rope-like fibres, while the woody central axis is small, and somewhat intermediate in structure between that of the Lepidodendroids and Gymnosperms. The roots (*Stigmaria*) usually start from the stem in four main branches, which divide dichotomously several times, and then continue in long extensions, which Sir J. W. Dawson considers are



Fig. 1390.—Stem of a semi-erect *Sigillaria* in a coal-seam; from Nova Scotia. (After Dawson.)

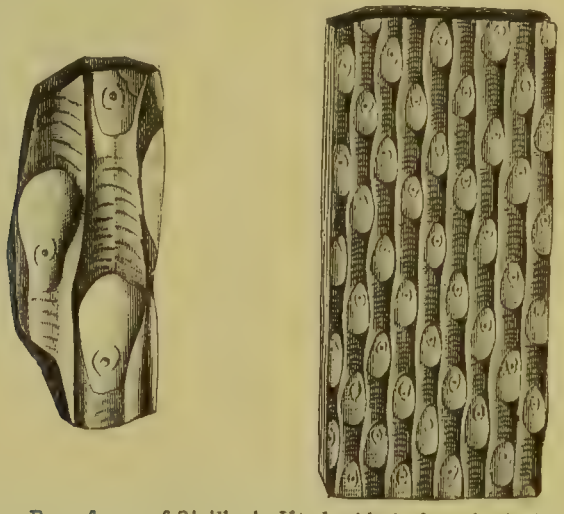


Fig. 1391.—Part of stem of *Sigillaria Utschneideri*; from the Carboniferous. The left-hand figure shows a small portion on a larger scale.

intended to afford a firm support in a soft marshy soil. The rootlets (fig. 1392) were arranged on the roots in whorls; and when

they decayed they left scars on the bark (figs. 1392 and 1393) corresponding to the leaf-scars on the stems. The nature of the fruit is still unknown, but it is probable that it more or less closely resembled that of the Lepidodendroids. Sir J. W. Dawson has, however, suggested that some of the Sigillarians may have had

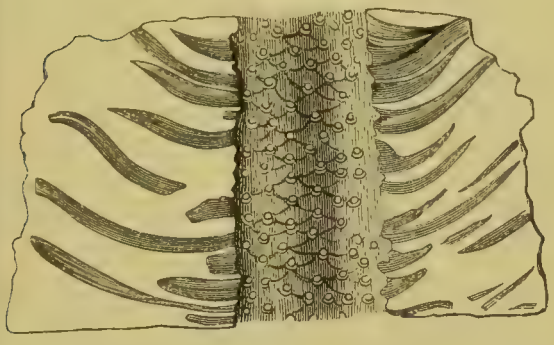


Fig. 1392.—Part of root of a Sigillarian or Lepidodendroid Tree (*Stigmaria ficoides*); from the Carboniferous. One-quarter natural size.



Fig. 1393.—Bark of a Sigillarian or Lepidodendroid root; from the Carboniferous. (After Dawson.)

fruit of the type of *Trigonocarpus* (fig. 1400), and that such forms consequently exhibit a connecting link between the Pteridophytes and the Gymnospermous Phanerogams.

The genus may be divided into several groups, which may eventually have to be raised to generic rank. The Clathrarian group (in which Mr Kidston includes some species of *Ulodendron*) has a thin bark, with the leaf-scars not in distinct rows, but having a spiral appearance; type, *S. discophora*, of Europe and the United States. In the Liodermarian group the ribs on the bark are obsolete, and the leaf-scars in distinct rows; type, *S. sydnensis*, of Australia. In the third, or Rhytidolepidian group, in which the Favularian group may be included, the ribs are narrow (fig. 1391) and often striate, and the leaf-scars large and hexagonal, or shield-shaped; type, *S. tessellata* (fig. 1389, B). Finally, the typical group is characterised by the broad ribs to the bark, of which the width usually exceeds that of the oval or elliptical leaf-scars; types, *S. reniformis* and *S. Browni* (fig. 1389, A).

CHAPTER LXVII.

SUB-KINGDOM CORMOPHYTA—continued.

Series Phanerogamæ.—Class Gymnospermæ.

Series III. Phanerogamæ.—The Phanerogams, which include the whole of the remaining groups of plants, are characterised by the production of a seed, and the consequent concealment or compression of the alternation of generations. It has already been mentioned that in several groups of Pteridophytes the tendency of the oöphore (prothallium) is to lose its independent existence, but in the present series this independence is totally suppressed. Thus the macrospore or female element, now termed the *embryo-sac*, is never detached from the main plant, or sporophore, previous to fertilisation; while the oöphore, now known as the *endosperm*, which may be rudimentary, is always enclosed in the macrospore (embryo-sac). The seed is developed from the *ovule* (of which the envelope is known as the *testa*), which produces the embryo-sac, and in this the endosperm and the *oösphere*. The latter is fertilised by the *pollen-tube* or outgrowth from the *pollen-grain*, which represents the microspore of the Pteridophytes.[1] The plant is always differentiated into stem, leaves, roots, and hairs; and its branching is normally monopodial, the main axis continuing to grow and producing its lateral shoots and roots beneath its apex. Phanerogams are further characterised by the metamorphosis and differentiation of homo-

[1] It is thus evident that the Phanerogam with its pollen-grains and embryo-sacs is equivalent to the sporophere of the Pteridophytes. The sexual differentiation, which in the most specialised members of the latter commences with the formation of macrospores and microspores, is, however, carried further back, being manifested not only in the formation of embryo-sac and pollen-grains, but also in the differences between ovule and pollen-sac, and between the modified leaves (*carpels* and *stamens*) bearing them, and, even earlier, in the distinction between male and female flowers, and finally in the development of separate male and female (*diœcious*) plants. At least for a time, the seed unites in itself the two generations—the prothallium (endosperm), and the embryo or young plant of the second generation. (Sachs.)

logous structures for the purpose of reproduction, as is shown in the flower, into the complex structure of which it will be unnecessary to enter here. The differentiation of the tissues is also more complex than in the Pteridophytes.

Phanerogams include the highest types of plant life, and it will be seen from the sequel how there has been a gradual advance in their degree of organisation as we ascend in the geological scale; the most specialised groups only making their appearance at a late epoch.

Class I. Gymnospermæ.—The first and most generalised class of Phanerogams is characterised by the ovules and seeds not being enclosed in the ovary, and by the early development of a distinct endosperm forming archegonia in which the oöspheres originate. The first leaves produced from the embryo are arranged in whorls of two or more; and the wood grows from the outside, forming annual rings of growth.

In many respects the existing Gymnosperms are intermediate between the Pteridophytes and the Phanerogams; and it is practically certain, as we have already hinted, that in past times there was a complete transition between the two series. The class includes the Cycads and Conifers and dates from the Devonian; but in the middle Mesozoic, which has hence been termed the "age of Gymnosperms," it attained its highest stage of development, and constituted the dominant type of the flora. The existing forms are usually arranged in three orders, while a fourth is frequently made for the reception of the extinct *Cordaites*.

Order 1. Cycadaceæ.—Existing Cycads (fig. 1394), which occur in the warmer regions of America and Asia, and also in South Africa



Fig. 1394.—A male Cycad (*Macrozamia spiralis*); from Australia. Greatly reduced.

and Australia, are low palm-like trees, with a short unbranched stem, occasionally divided into two, marked by leaf-scars. The leaves form a crown, and, except in one genus where they are

bipinnate, are simply pinnate; their structure is very firm, and they usually develop in a circinate manner like ferns. The plants are male and female; the male fructification being borne in cones (fig. 1394), while in the female the ovules are usually situated on the margin of modified leaves or on the base of scales.

Existing Cycads are divided into the families *Cycadeæ*, *Encephalarteæ*, *Stangerieæ*, and *Zamieæ*. Of these the living South African genus *Encephalartos* occurs in the Miocene of Eubœa, and perhaps in the Rhætic of Honduras; while a leaf from the Miocene of Styria has been referred to the Mexican genus *Ceratozamia*, belonging to the *Zamieæ*.

The family position of extinct genera is for the most part uncertain, and it is accordingly unadvisable to make any attempt at such divisions. As is usually the case with fossil plants, genera have been founded upon different portions of the organism, so that in many cases we doubtless have the same type described under two or more names. In the Mesozoic, as Sir J. W. Dawson remarks, Cycads had a world-wide distribution, and many of the undermentioned European genera likewise occur in America. The species occurring in the Cretaceous of Greenland are, according to the same authority, of small size and low growth, so that they may have been protected from the winter snows. Some of the more southern forms attained, however, a considerable height, and must have resembled palms. The order is known from the Carboniferous upwards.

Genera founded on Leaves. — The genera based on the evidence of leaves will be taken first. Of these *Cycadites* has the leaflets attached by the whole width of their base to the stem, with a single vein, while the young leaves are circinate; in all of which respects it approximates to the existing *Cycas*. It occurs in Europe from the Carboniferous to the Upper Cretaceous; and in India it is characteristic of the Upper Gondwanas. *Podozamites* with small leaves, and the leaflets alternating and narrowed at the base, ranges in Europe from the Rhætic throughout the Jurassic and into the Lower Cretaceous; it is also found in the Dakota Cretaceous, in the Upper Gondwanas of India, and in the reputed Trias of New Zealand. Till something is known of its fructification the affinities of this genus cannot be determined. *Zamites*, again, is a very large genus with small or medium-sized leaves, in which the leaflets are attached by a calus to the upper surface of the stem, and are subject to a considerable variation of form. In Europe this genus is well represented from the Middle Trias to the Upper Cretaceous (Greenland), an isolated species being found in the Miocene. It is also recorded from the reputed Trias of New Zealand, and the Upper Gondwanas of India. *Glossozamites* includes large-leaved Cycads with subsymmetrical leaflets, occurring typically in the European

Wealden, but according to Dr Feistmantel also represented in the Lias and the Lower Gondwanas of India. *Ptilophyllum* (fig. 1395) is a genus characteristic of the Upper Gondwanas, having long narrow leaves, with alternating leaflets which are likewise long and narrow, and are attached to the front of the stem, with upwardly-directed terminal points, and a simple venation. *Otozamites* (fig. 1396),

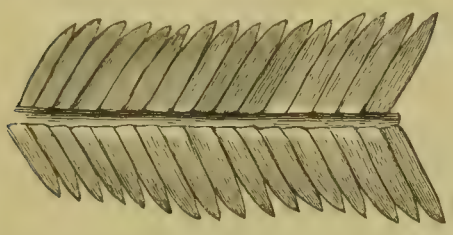


Fig. 1395.—Part of leaf of *Ptilophyllum cuchense*; from the Upper Gondwanas of India. (After Feistmantel.)



Fig. 1396.—Part of leaf of *Otozamites bengalensis*; from the Lower Gondwanas of India. (After Feistmantel.)

according to the last-named writer, is allied to *Ptilophyllum*, but distinguished by the lower basal angle of the leaflets, which in the latter is affixed and decurrent on the stem, becoming free and rounded like the upper one; the disposition of the veins being very similar in both genera. In Europe this genus occurs very abundantly from the Rhætic to the Upper Jurassic, is well represented in the Cach stage of the Upper Gondwanas of India, and also occurs in the Rhætic of Honduras. *Ctenophyllum* is an allied genus typically from the Upper Lias and Lower Jurassic of Europe. An important genus is *Pterophyllum*, in which Dr Feistmantel includes *Anomozamites* of Schimper, occurring in Europe from the Carboniferous to the Upper Jurassic and Wealden, in India from the higher stage of the Lower Gondwanas to the two lower divisions of the Upper Gondwanas, and also recorded from the reputed Trias of New Zealand. The leaves are stalked, of moderate size, and considerable width; while the leaflets are generally opposite, articulating at right angles with the sides of the stem, and having numerous veins. *Ptilozamites* is an allied type from the Rhætic of the Continent. *Nilssonia*, of the Rhætic and Lower Jurassic of Europe, is readily distinguished by its leaves being either strap-like and undivided, or with slight segmentation. *Sphenozamites* from the French Jurassic and the Rhætic of Honduras, and *Macropterygium* from the Keuper of Carinthia, are imperfectly known forms which may be allied to *Nœggerathia* noticed below. *Dictyozamites* is a peculiar form from the Upper Gondwanas characterised by the leaves having a net-like venation, as in the genus *Glossopteris* (fig. 1376) among the Ferns, and is regarded by Dr Feistmantel as the type of a distinct family. Another type is presented by the genus

Rhiptozamites from the Jurassic of Siberia, to which *Nœggerathiopsis* of the Lower Gondwanas of India, the Hawkesbury beds of Australia, and the Rhætic of Honduras, is closely allied, if indeed it be generically separable. It is known by specimens which appear to be leaflets of a pinnate leaf, and are of an elongate form with forked radiating veins which do not converge towards the summit.

Genera founded on the Fructification.—The name *Cycadospadix* has been applied to the female fructification of Cycads from the Lower Lias and Corallian closely resembling that of *Cycas*. Cones from the Lias to the Wealden have been described as *Zamiostrobus* and *Beania;* while seeds, ranging from the Keuper to the Wealden, are known as *Cycadeospermum*.

Genera founded on Stems.—Stems of Cycads are of not uncommon occurrence, especially in fresh-water deposits, and are locally known to the quarrymen of the south of England as "fossil birds'-nests." According to the arrangement of Count Saporta they may be classified as follows: *Bolbodium*, from the Lias and Corallian; *Cylindropodium*, from the Lower Lias and Upper Jurassic; and *Mantellia* (fig. 1397), also known as *Cycadoidea* or *Clathropodium*, from the Upper Jurassic and Wealden, which is especially common in the "dirt-bed" of the Isle of Portland. Other stems, ranging from the Jurassic to the Lower Greensand, have been described by Mr Carruthers under the name of *Bennettites;* the associated fructification differing in several respects from that of existing types. The preceding forms have comparatively short stems, but in *Platylepis*, of the Lias, and *Fittonia* and *Bucklandia*, of the Upper Jurassic and Wealden, the stems may attain a height of several feet.



Fig. 1397.—Stem of *Mantellia megalophylla;* from the Purbeck of the Isle of Portland. Reduced.

Here we may notice the remarkable genus *Williamsonia*, ranging from the Rhætic to the Jurassics of Europe, in regard to the serial position of which there has been much discussion. It is based on the fructification, which in some cases is found attached to stems with spirally arranged leaves. It has been suggested that this plant may belong to the Dicotyledons, while Mr J. S. Gardner considers that its affinities are with the monocotyledonous *Pandanaceæ;* but it appears quite possible that it may really prove to be an extremely aberrant Cycad. This genus is also found at the base of the Upper Gondwanas of India.

Transitional Types.—The families *Nœggerathieæ* and *Cordaiteæ*, of the Palæozoic, appear to include types which are in many respects transitional between the existing Cycads and Conifers, and may therefore provisionally occupy an intermediate position. Both families are, indeed, referred by Mr Kidston to the Cycads, but other writers would place some or all of these forms with the Conifers. In the first family the type genus *Nœggerathia*, which occurs in the European and North American Carboniferous, has the leaves arranged in two opposite rows (distichous), these

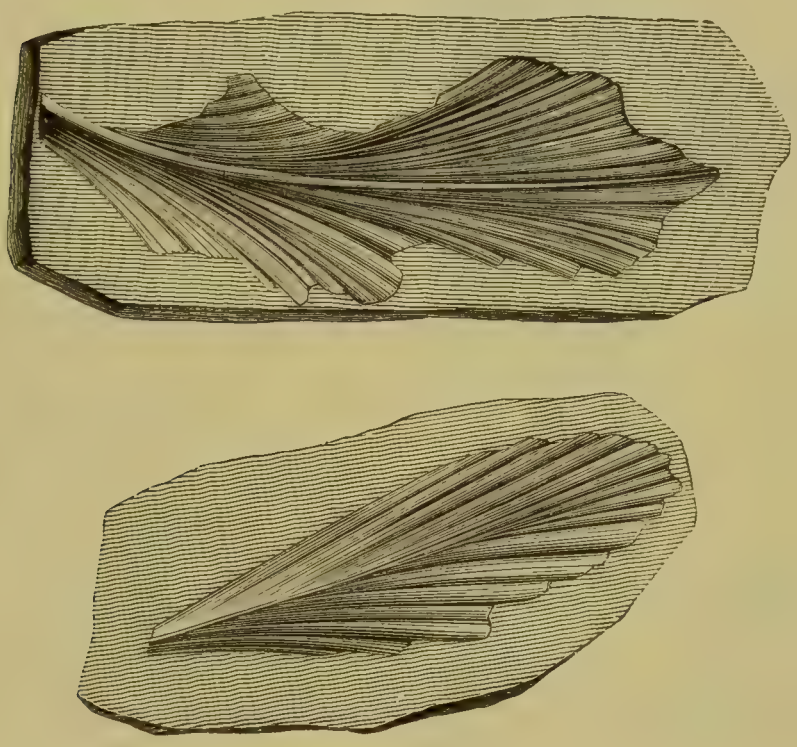


Fig. 1398.—Leaves of *Psygmophyllum expansum*; from the Permian of Russia.

leaves having a cuneiform base, with radiating veins which do not form forks. *Psygmophyllum* (fig. 1398), or *Gingkophyllum*, is an apparently allied type from the European Carboniferous and Permian, which is placed by Dr Schenk with the Taxoid Conifers. A branch from the upper Devonian of Wyoming, described by Sir J. W. Dawson as *Dictyocordaites* is stated to connect *Nœggerathia* with the under-mentioned genus *Cordaites*; since, in place of the parallel venation of the latter, the veins fork at an acute angle, and are slightly netted by the spreading branches of one vein uniting with those of an adjacent one. The

second family is represented by the genus *Cordaites* (fig. 1399), ranging from the Devonian to the Permian, and occurring in both the Old and New Worlds. These plants formed trees reaching to a height of 20 or 30 feet, with the stems marked by transverse leaf-scars, and the leaves arranged in whorls; the leaves themselves (fig. 1399) being comparatively broad, with parallel longitudinal veins, and attached by a somewhat wide base. Their fructification consisted of male and female catkins, forming long racemes (fig. 1399), and known as *Antholithus;* which subsequently produced berries known as *Cardiocarpus*, some of which appear to have had wing-like envelopes, while other types had a soft pulpy cover like those of the existing Yews. The stem had a large central pith surrounded by scalariform tissue with a cylinder of woody wedges; the casts of these pith-cavities are included among the so-called *Sternbergia*, to be shortly mentioned. According to Dr Schenk the female fructification of *Cordaites* is most like that of the Cycads, while the male fructification and the structure of the stem comes nearest to the Conifers.



Fig. 1399. — A branch of *Cordaites;* from the Carboniferous. Reduced. (After Grand' Eury.)

In this place certain Carboniferous fruits which have not at present been referred to their respective plants may be conveniently noticed. These have been named *Rhabdocarpus*, *Carpolithus*, *Trigonocarpus* (fig. 1400), and *Palæoxyris*. They are large and angulated nut-like fruits, resembling those of the Yews. Specimens of *Trigonocarpus* are extremely numerous in some of the coal-measures; a slab of sandstone in the British Museum measuring 21 × 15 inches containing more than 400 of these nuts. The sug-



Fig. 1400. — *Trigonocarpus Parkinsonsi;* from the Carboniferous of England. (After Lindley and Hutton.)

gestion of Sir J. W. Dawson that some of these fruits may belong to Sigillarians has been already mentioned, but most recent authorities agree in regarding them as belonging to *Cordaiteæ* or Conifers.

Order 2. Coniferæ.—This order includes the existing Yews, Pines, and allied forms, and is of considerable palæontological importance, although the different groups can be but very briefly mentioned in this work. Conifers are characterised by the strong and continuous growth of the main axis, which forms a slender conical stem sometimes exceeding 200 feet in height; on this main stem the lateral axes, or primary branches, arise either in rosettes at intervals, or irregularly, and again subdivide in the same manner; the whole contour of the tree thus forming a more or less regular cone. The leaves may be either all foliage leaves containing chlorophyll; or all colourless or brownish scales; or a mixture of foliage leaves and scales. The foliage leaves are mostly small and simple, and very rarely compound; and thus form a striking contrast to the Cycads, where the leaves constitute the greater part of the plant. The flowers are always of separate sexes; but the trees themselves may either bear one or both kinds of flowers. These flowers are never terminal on the main axis, and are subject to great variation of structure in the different families. The male flowers are not of much importance to the palæontologist, who has more often to deal with those of the female. The best known examples of the latter are the cones of the *Abietineæ*, which are modified shoots bearing a number of closely packed woody scales, on which the ovules are usually placed in pairs.

The earliest fossils referred to the Coniferæ are trunks of large trees occurring in Europe and North America, from the Carboniferous to the Permian, and described under the names of *Dadoxylon*, *Araucarioxylon*, or *Pinites*. These stems exhibit the woody structure characteristic of existing Conifers, and Sir J. W. Dawson states that they are found in association with leaves of Permian genera of *Walchieæ* noticed below, and consequently places them in that family. It has, however, been suggested that at least some of these stems belong to the *Cordaiteæ*, although strong reasons have been propounded against the acceptance of this view. Some of the curious ringed cylinders described under the name of *Sternbergia* or *Artisia* are casts of the pith-cavity of *Dadoxylon*. Stems from the coal-measures have been found with a length exceeding 70 feet.

Leaving these doubtful forms we may proceed to the consideration of the five existing families into which the order may be divided. The *Taxineæ*, or Yews and their allies, have their leaves, which are often of considerable width, arranged spirally; the flowers typically dicœcious; and with the ripe seed enclosed in a fleshy envelope. We have already mentioned that *Psygmophyllum* (*Gingkophyllum*) is

placed in this family by Dr Schenk; but exclusive of this form we have several genera allied to the existing *Salisburia* or Gingko-tree of Japan and China, characterised by its fan-like leaves (fig. 1401).

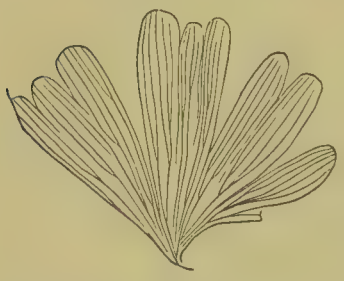


Fig 1401.—Leaf of Gingko-tree (*Salisburia siberica*); from the Lower Cretaceous of Siberia. (After Dawson.)

This genus had an almost world-wide distribution in past times, being abundantly represented from the Permian, and if *Saportea*, from the Carboniferous of Pennsylvania, be rightly included, extending as low as the preceding period. It is very curious, as Sir J. W. Dawson remarks, that this genus should now be restricted to a single Asiatic species, although it will grow in temperate Europe and America, without, however, usually producing fruit. In India it occurs in the Upper Gondwanas. *Rhipidopsis*, from the Lower Jurassic of the Atlas and the Lower Gondwanas of India, is an extinct genus with large leathery leaves usually divided into five wedge-shaped segments, of which the middle one is the largest. Other extinct genera are *Dicranophyllum*, from the Carboniferous of France, China, and Canada; *Trichopitys*, from the Jurassic of Europe; the allied *Czekanowskia*, from the European Rhætic and Jurassic, the Jurassic of China, the Wealden of Portugal, and the Upper Gondwanas of India; and *Fieldenia* and *Phœnicopsis*, the former being from the Miocene of Spitzbergen, and the latter from the Jurassic of Northern Europe and the Upper Gondwanas. Many of these genera have the leaves divided into long slender slips, but in the true Yews the leaves are simply acicular. The existing genus *Taxus*, together with the closely allied or identical *Taxites*, has a wide distribution, being well represented in the Tertiaries and extending down through the Jurassic to the Rhætic. The allied *Cephalotaxus*, of China and Japan, in which the male flowers are in clusters, and the seed is completely enveloped in the fleshy capsule, is represented in the Tertiary and Cretaceous of Greenland; while another existing genus, *Torreya*, occurs in the Tertiaries of Greenland and America. Finally, omitting some less important types, the tropical genus *Podocarpus* occurs abundantly throughout the Tertiaries of the greater part of the world.

The genus *Walchia* (fig. 1402) may be taken as the representative of a group—the *Walchieæ*—which may perhaps serve to connect the Yews with the Araucarias. In the type genus the secondary branches or twigs are arranged alternately in two rows, and carry spirals of angulated acicular leaves; larger leaves covering the primary branches in an imbricating manner. The fruit, according to Dr Schenk, formed true cones, approximating to those of the

Araucarias; but it should be observed that Sir J. W. Dawson considers that their fruit was not in the shape of cones, but was of the type of that of the Yews. This genus occurs in the Permian of Europe and North America. *Ullmania*, of the European Permian and Keuper, is an apparently allied type in which cones are known to have been developed.

In the same family Dr Schenk places the genus *Pagiophyllum* (*Pachyphyllum*), which has thick leathery leaves of triangular form,



Fig. 1402.—Part of branch (*a*) and twig (*b*) of *Walchia piniformis*; from the Permian of Saxony. (After Gutbier.)

arranged spirally on the stem and branches, and uniting at their bases. In Europe it occurs from the Bunter to the Lower Cretaceous; it has also been recorded from the Upper Gondwanas of India, but some of the species from those beds seem to belong to *Araucaria*, to which this genus appears to be nearly related.

The *Araucarieæ* are too well known to require much description; typically they are lofty evergreen trees, with verticillate spreading branches, covered with stiff and flattened leaves, with sharp points, and usually imbricating. The cones are large, globular, and terminal. The existing species are mostly confined to the southern hemisphere, and belong to three genera. Of these, *Dammara*, which extends into the Malay Peninsula, and affords the well-known gum-damar, may be represented in the Upper Cretaceous of Greenland and the United States; but the specimens from the Cretaceous described as *Dammarites* may apparently be cones of Cycads. *Araucaria* itself is now chiefly known from Australia, New Guinea, Norfolk Island, and South America, but in past times had a much wider distribution. Thus it occurs in the Tertiary of the Arctic regions, in the English Eocene, in the Dakota stage of the American Cretaceous, and right through the Wealden and Jurassic of Europe. It also occurs in the Indian Gondwanas, where some of the species have been described as *Araucarites*, while the figured specimen (fig. 1403), which was referred by Dr Feistmantel to

Pagiophyllum, is regarded by Dr Schenk as inseparable from the existing genus. The extinct genus *Cunninghamites* is founded on branches which appear to closely resemble those of the existing *Cunninghamia* of China; it occurs in the Upper Cretaceous and Miocene of the Continent, and the Cretaceous of the United States. Finally, the genus *Albertia*, from the Bunter of Alsace and the Lower Gondwanas of India, may be mentioned here, although it is not certain that its true position is not with the *Abietineæ*.



Fig. 1403. — Branch of *Araucaria* (*Pagiophyllum*) *divaricata*; from the Upper Gondwanas of Cach. (After Feistmantel.)

The family *Taxodineæ* is another ancient type represented from the Permian upwards. The leaves are generally more or less linear, and may be arranged in two rows, or crowded together at the ends of the branches. In *Taxodium* and *Glyptostrobus* the lateral shoots are deciduous. The oldest genus is *Voltzia* (*Glyptolepis*, *Glyptolepidium*), of the Permian and Trias of Europe and the Lower Gondwanas of India; followed by the allied *Leptostrobus*, of the Lower Jurassic of Siberia. *Cyclopitys*, again, from the latter deposits and the Lower Gondwanas of India, is considered to be an ancestral type of the existing *Sciadopitys* of Japan, which connects the typical members of the family with the *Abietineæ*. The genus *Taxodium* is now known by two species from North America, of which *T. distichum* dates from the Upper division of the Laramie beds, and occurs also in the Eocene of Utah, whence it can be traced through the Tertiaries of Alaska, Canada, Greenland, and Spitzbergen, and thus to the Upper Miocene of Œningen in Switzerland. The closely allied *Glyptostrobus* of China, readily characterised by the sculptured scales of the cones and small leaves, has a somewhat analogous distributional history; thus it first appears in the Lower Cretaceous of Greenland, and is also found in the upper part of the same system; thence it extends in one direction through Arctic America to the United States, where it is found in the topmost beds of the Laramie, and in another to Europe, where its range extends from the Lower Miocene (Oligocene) to the Pliocene; *G. europeus* being common to Europe and the Laramie beds. The well-known *Sequoia* (*Wellingtonia*), in which the scales of the cones, instead of imbricating as in the preceding genera, form woody pyramids at right angles to the axis, is now known by two Californian species. Of these *S. sempervirens* has erect leaves arranged in two rows and small round cones; while *S. gigantea*, the "Big tree," has smaller

leaves crowded together, and larger egg-shaped cones. It is remarkable that these two types are represented by allied species in the Lower Cretaceous, where we also find species which are intermediate, and both types continue right through the Tertiaries of Europe and North America, which are connected by the Greenland deposits; while one species has also been found in the Eocene of Australia. Altogether twenty-six species are known.

"This," as Sir J. W. Dawson observes, "is perhaps the most remarkable record in the whole history of vegetation. The Sequoias are the giants of the Conifers—the grandest representatives of the family—and the fact that, after spreading over the whole northern hemisphere and attaining to more than twenty specific forms, their decaying remnant should now be confined to one limited region in America, and to two species, constitutes a sad memento of departed greatness. The small remnant of *S. gigantea* still, however, towers above all competitors as eminently the 'big trees'; but had they and the allied species failed to escape the Tertiary continental submergences and the disasters of the glacial period this grand genus would have been to us an extinct type. In like manner the survival of the single Gingko of Eastern Asia alone enables us to understand that great series of taxine trees with fan-like leaves of which it is now the sole representative."

Geinitzia, from the Upper Cretaceous and Lower Tertiary of both Europe and North America, appears to connect the preceding with the following genus: it has alternating branches, with two rows of small sickle-shaped leaves, between which are scale-like leaves and elongated persistent cones. *Brachyphyllum* is characterised by its extremely short and thick scale-like leaves, which are spirally arranged; it occurs in Europe from the Rhætic to the Wealden, and is also found in the North American Cretaceous. An allied extinct genus is the remarkable *Echinostrobus*, of the Upper Jurassic of Europe and the Indian Upper Gondwanas, in which the stem is flattened, and the branches are covered with imbricating scale-like leaves; while the club-like cones are borne at the summits of short lateral branches. Other extinct genera of this family are *Cyparissidium* from the Rhætic and Upper Cretaceous of Europe; *Inolepis* of the Upper Cretaceous of Greenland; *Chirolepis* from the Rhætic and Lias of France and Switzerland; and *Swedenborgia* from the Rhætic of Palsjö.

The *Cupressineæ*, including the Cypresses, Junipers, and Thujas, are moderate sized or shrub-like trees, usually with very minute scale-like leaves closely adherent to the branches, and generally arranged in two, although sometimes in three or four rows. In some cases, however, the leaves are linear, especially in the young. This family dates from the Upper Trias, and is represented at the present day by some twelve genera. One of the earliest known genera is *Widdringtonites*, from the Keuper of the Continent and the

Jurassic of Europe and the United States; it appears to be in some respects intermediate between other Conifers and the next genus, and its reference to this family is provisional. The existing South African genus *Widdringtonia*, in which the leaves are alternate and crowded, and in the young plant linear, is represented in the Continental Miocene; while *Callitris* from the northern part of the same continent was likewise widely spread over Europe in the Middle Tertiary. In the Upper and Lower Cretaceous of Europe, and also in North America, we meet with the extinct genus *Frenelopsis*; while in the Tertiaries allied forms have been referred to the existing genera *Frenela* and *Actinostrobus*, now confined to the Australian region; *Librocedrus*, which has now a much wider distribution than the latter genera, dates from the higher Cretaceous of Greenland and the United States, and is well represented in the Lower and Upper Miocene of Europe. In *Moriconia* of the Upper Cretaceous of Greenland and Germany, and the Dakota Cretaceous of America, and *Thujites* ranging from the Rhætic[1] to the Upper Jurassic, we have two genera of which the precise affinities are difficult to determine. Of the remaining existing genera known to occur in a fossil state, *Thuja* is found in amber, and has also been recorded from the Upper Cretaceous and Miocene of North America, but these forms are regarded by Dr Schenk as probably referable to *Chamæocypris*. *Biota* of Japan and China, and *Thujopsis* of Japan, occur in the Miocene of Greenland; *Chamæocypris*, of North America and Japan, dates from the Lower Eocene and Miocene of Europe, and probably from the American Cretaceous; *Cupressus* (Cypress), which has a wide distribution in the northern hemisphere, is probably found in amber; while *Juniperus* (Juniper) dates from the Upper Cretaceous of America and Greenland. Finally, *Palæocyparis* which occurs throughout the European Jurassic, and *Phyllostrobus* of the Kimeridgian of France, are allied extinct types. The last family of Conifers is the *Abietineæ*, including the Pines, Spruces, Larches, and Cedars, all of which have tall symmetrical stems, and usually spirally-arranged linear leaves, which may be either flattened or angulated. The cones are usually large and pyriform, with two seeds beneath each scale. We may first mention the extinct genera *Elatides* and *Palissya*, of which the family position is uncertain, since they show some characters of the Pines and others of the Yews. The former occurs in the Jurassic of Siberia, but some of the forms appear to be *Araucarieæ*; while the latter is found in the European Rhætic, the Lower Gondwanas of India, the Australian Newcastle beds, and the reputed Trias of New Zealand. The existing types are usually divided into a number of genera, such as *Pinus* (true Pines), *Abies* (Spruce),

[1] The form from the Carboniferous described under this name is probably a Lepidodendroid.

Larix (Larch), *Cedrus* (Cedar), &c., but the generic determination of many fossil types is extremely difficult, and we can only state here that the group as a whole has undoubtedly existed from the Jurassic, and may not improbably date from the Lias or Rhætic. Finally, the family position of the imperfectly known Rhætic genus *Camptophyllum* cannot at present be determined.

Order 3. Gnetaceæ.—This small order, represented by the genera *Ephedra*, *Gnetum*, and *Welwitschia*, is not certainly known to be represented in a fossil state, although several forms have been referred to the first-named genus.

CHAPTER LXVIII.

SERIES PHANEROGAMÆ—continued.

Class Angiospermæ.

Class II. Angiospermæ.—With this class we come to the highest development of plant life, characterised by the complete enclosure of the ovules and seeds in the ovary, and by the more or less rudimental condition of the endosperm. As they are highest in point of development, so these plants are characteristic, as a whole, of the latter periods of the earth's history, so that the Tertiary and recent periods are well described as the "age of Angiosperms." The class may be divided into the two great subclasses of Monocotyledons and Dicotyledons, of which the former is the more generalised, and the first to make its appearance in time.

Subclass I. Monocotylæ.—The Monocotyledons are plants having only a single seed-leaf or *cotyledon;* and with an endogenous, or inwardly growing stem, in which there are consequently no annual rings of growth. It includes the Palms, Grasses, Lilies, &c.; and it appears that the Palms and Grasses are the earliest known forms; the perianthed types, or those with large and conspicuous flowers, not making their appearance till a later date.

There is indeed some doubt as to the earliest appearance of the subclass, but it appears to be certain that most of the Palæozoic forms which have been described as Monocotyledons are referable to Gymnosperms. There occur, however, certain forms of doubtful affinity in the Upper Palæozoic, which have been termed "pro-Angiosperms," or types imperfectly developed from a Pteridophytic or Gymnospermic stock, which we may proceed to notice. The best known is the genus *Spirangium*, ranging from the Carboniferous to the Wealden; this is based on certain spindle-like bodies, which are believed to consist of from five to ten linear valves enclosing a central cavity, the valves being in some cases spirally twisted. Their affinities are at present totally obscure. From the Russian Permian

a leaf with a net-like venation described under the name of *Dichoneuron*, has been regarded as a Monocotyledon, but apparently on quite insufficient grounds. The genus *Œthophallum*, from the Trias of the Vosges, which has linear leaves arranged in groups of three on the branches of a woody stem, and long seed-bearing spikes, has also been referred to this subclass. Certain fruit-spikes from the same deposits described as *Echinostachys* may belong to kindred types. Again, the long ribbon-like leaves found in the Rhætic and Jurassic and known as *Yuccites*, have been looked upon as indicating plants allied to the existing *Dracæna;* but it is quite possible that remains of totally distinct types of vegetation have been included under this name. In the Upper Trias and Lias of Switzerland occurs the imperfectly known *Bambusium*, which Mr J. S. Gardner regards as an undoubted Monocotyledon, although Dr Schenk suggests affinity with the Equisetaceæ. The former writer also regards as Monocotyledonous a stem from the Yorkshire Oolites described as a Calamite. Plants from the Jurassic which have been named *Naiadita*, *Bensonia*, &c., are not Phanerogams at all; while *Aröides* of the Great Oolite is based on a Crinoid. Stems with a rush or grass-like form from the Purbeck appear, however, to be true Monocotyledons. Finally, *Rhizocaulon*, from the Upper Eocene of the Paris basin, is based on the evidence of a stem which may indicate a plant allied to the *Cyperaceæ*.

Leaving these doubtful types, we may proceed to the consideration of Monocotyledons which can be systematically placed.

Order 1. Liliifloræ.—This order includes the Lilies, Irises, Yuccas, and their allies, most of which have conspicuous perianthed flowers, which vary considerably in structure, and may be of large size. The plants may be perennial, but are more usually annual, with rhizomes or bulbs. The *Liliaceæ* (Lilies, Tulips, Aloes, Yuccas, &c.) are but of little palæontological importance. From the Eocene and higher Tertiaries plants have been described under the names of *Agavites*, *Yucca*, and *Dracæna*, the two last being existing genera; but Dr Schenk considers that most of these belong to *Dracæna* (Dragon-tree), now found in the Canaries, Africa, and India. Plants of the genus *Smilax*—the type of a subfamily of *Liliaceæ*—occur in the European Tertiaries from the Eocene upwards; although it seems doubtful if forms described as *Smilacina* and *Majanthemophyllum* really belong to this group. The *Juncaceæ*, or Rush family, are known by species of *Juncus* from the Upper Miocene of Œningen; and, according to Dr Schenk, a species of *Iris* from the same deposits is the only fossil representative of the *Iridaceæ*, although several other fossils have been described under that name. In the *Dioscoreaceæ* (Yams), *Dioscorites*, from the European Miocene, is probably allied to *Dioscorea;* while in the Pine-apple family, or

Bromeliaceæ, the typical *Bromelia* apparently occurs in the same deposits. Other fossils referred to these families are, however, distinct.

Order 2. Enantioblastæ.—There is some uncertainty as to whether this small order is represented in a fossil condition, but it is not improbable that *Eriocaulon* occurs in the Tertiary of the United States.

Order 3. Spadicifloræ.—With this order, which comprises the Palms, Screw-pines, and Arums, we come to one of considerable palæontological importance, as including several of the earliest representatives of the class. They are typically tall plants, with large wide-spreading leaves, and the inflorescence forming a spadix, generally enveloped in a large spathe, and without a petalled perianth; the seed being generally large, and often of huge size. The first family of the *Palmaceæ* now includes about one thousand species from the warmer regions of the globe, and dates back to the Upper Cretaceous. In the higher Cretaceous of Europe we meet with Palms referred to the extinct genus *Flabellaria*, which also ranges into the Miocene, and has been recorded from the Cretaceous of the United States. *Fasciculites*, from the Cretaceous of Greenland, is regarded

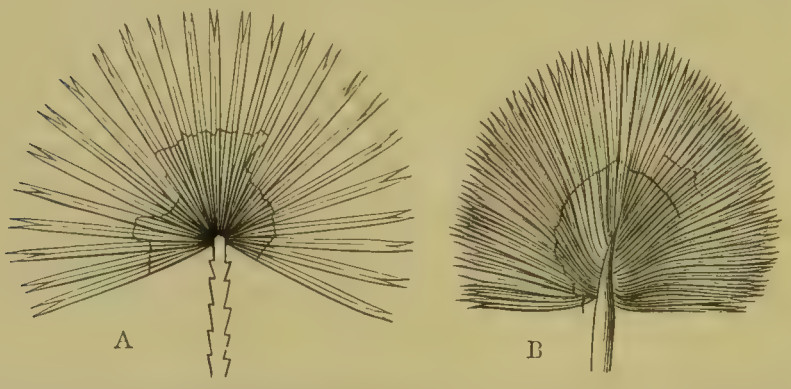


Fig. 1404.—A, Leaf of *Chamærops helvetica*; from the Upper Miocene of Switzerland. B, Leaf of *Sabal major*; from the Lower Miocene of France. Reduced.

with some hesitation as a Palm-stem; and Mr Gardner figures Palm-wood from the Folkestone Gault; but many other earlier fossils, such as *Palæospathe*, are not Palms at all. In the Tertiary Palms are abundant, and from the Eocene to the Upper Miocene we meet with forms with pinnate leaves allied to the existing *Phœnix* (Date-palm), which have been described under that name, or as *Phœnicites* and *Calamopsis*. Of the group with fan-like leaves we have already mentioned *Flabellaria*, and throughout the European Tertiary there occur leaves referred to the Old World genus *Chamærops* and to *Sabal* of North America (fig. 1404); both of which genera have a more northerly distribution than any other types. *Sabal*

major (fig. 1404) occurs in the Lower and Middle Miocene of Europe, and also in the Miocene of Northern India; while remains of the same genus have been described from the Tertiary of the United States. In the Lower Eocene of Europe and the Chalk of Fuveau large fruits occur known as *Nipadites* (fig. 1405), from their resemblance to the triangular fruits of the Oriental and Australasian genus *Nipa*, which some writers class with the Palms and others with the *Pandanaceæ*. There is considerable doubt whether the small family *Cyclanthaceæ*, of tropical America, is represented in a fossil state, but fragmentary leaves from the Lower Eocene of Sézanne have been described as *Ludoviopsis*, from their supposed resemblance to those of *Ludovica*. The well-known *Pandanaceæ*, or Screw-pines, are trees or shrubs with long simple imbricated leaves, usually spined on the edges and back, and unisexual or polygamous flowers, without perianth, and covering the whole of the spadix; the fruit being in the form of drupes with single seeds, or berries with numerous seeds. All the living forms are tropical. Leaves from the Tertiary and Upper Cretaceous of Europe have been referred to *Pandanus;* but it is a question whether at least some of these do not indicate a distinct genus. In the Cretaceous and Jurassic of Europe, extending as far north as Greenland, there occur fruits to which the name *Kaidacarpum*[1] has been applied, and which are regarded by their describer, Mr Carruthers, as undoubtedly Pandanaceous, although Dr Schenk is not absolutely satisfied of the correctness of this reference. The fruit consists of a thick spadix, with bunches of drupes, each of which contains a single seed; the whole arrangement being strikingly like that of the existing *Sussea*. *Podocarya* is an apparently allied fruit from the Inferior Oolite; and some authorities regard *Williamsonia* (p. 1528) as related to this genus. *Goniolina*, from the Kimeridgian and Corallian of France, is founded on compound fruits which are compared by Mr Gardner to those of *Pandanus*, and of which the description is as follows:—



Fig. 1405.—Fruit of *Nipadites ellipticus;* from the London Clay. Reduced.

"Small ovoid aggregated fruits, like those of *Pandanus*, borne on a naked, cylindrical, and relatively slender petiole. The heads of the very numerous fruits are arranged in spirals and regular, pressed together, and barely a millimetre across. They are of hexagonal shape, and six keels extend from the angles and meet in a raised point at the centre. The interior axis is cylindrical, and impressed by scars made by the bases of the fruits, completing its likeness to *Pandanus*."

[1] Correctly *Cædacarpum*.

The reed-like plants of the family *Typhaceæ* occur throughout the Tertiary, where we have *Typha* (Reed-mace) or the allied *Typhæoloipum*, and *Sparganium*, although it is doubtful if the Cretaceous plants referred to these genera are rightly named. The *Araceæ* (Arums and their allies) appear to date from the Upper Cretaceous, although it is extremely uncertain if the Tertiary plants described as *Aröites* and *Aronites* really belong to this family. *Acorus* (Sweet-flag) occurs in the Miocene of Spitzbergen, and is also found in amber; and *Pistia*, a tropical water-weed allied to the common



Fig. 1406.—A, Fruiting-organ of *Goniolina*; B and C, The individual fruits enlarged; from the Kimeridge Clay of France. (After Saporta and Marion.)

Duck-weed (*Lemna*), occurs in the Laramie beds of America and the Upper Cretaceous of the Continent; but the plants from the Westphalian Chalk and the Laramie beds, described as *Pistites* and *Lemnophyllum*, according to Dr Schenk, are not Monocotyledons. *Lemna* has been described from the Laramie and Middle Tertiary of North America, and also from the Miocene of Würtemberg. *Pothocites*, of the Carboniferous, which has been referred to this family, is part of a Sigillarian. In the aquatic *Naiadaceæ* we have remains of the fluviatile genera *Posidonia* and the marine *Zostera* (*Zosterites*) dating from the Upper Cretaceous of both the eastern and western hemispheres. *Cymodocea* may also date back to the Eocene, although many of the forms described under its synonym of *Caulinites* are totally different. *Naias* occurs certainly in the Miocene of Œningen, and perhaps in lower beds; while *Potamogeton* (Pond-weed), with its dimorphic leaves, dates from the Upper Eocene of Aix, and is also found in the Tertiaries of North America.

Order 4. Glumifloræ. — This order includes the Grasses, Sedges, &c., and is of but little importance to the palæontologist. In the *Gramineæ*, exclusive of some very doubtful forms, we may notice that *Bambusa* (Bamboo) occurs in the Pliocene of Europe;

but that the so-called *Bambusium* is probably Equisetaceous. *Arundo* and the allied *Phragmites* are stated to make their first appearance in the Upper Cretaceous of both hemispheres; while *Pseudophragmites* and *Arundites*, dating from the Eocene, are more or less closely allied extinct types. In the *Cyperaceæ* (Sedges) numerous fossil Tertiary plants have been described as *Carex*, *Cyperus*, *Cyperites*, and *Scirpus*, the former being also recorded from the Laramie; but all these determinations are exceedingly doubtful, and it can only be stated with certainty that *Cyperus* occurs in the Œningen Miocene.

Order 5. Scitamineæ.—The past history of this large tropical order is even more imperfect than that of the last. In the *Musaceæ* (Plantain) large leaves, from the Eocene and higher Tertiaries, have been described under the names of *Musaphyllum* or *Musa*, but Dr Schenk suggests that some at least of these may belong to the *Araceæ*. Under the name of *Zingiberites* imperfect leaves, from the Upper Cretaceous of Greenland and the Swiss Tertiary, have been regarded as indicating fossil *Zingiberaceæ;* and a similar position has been given to *Amomocarpum* and *Amomophyllum* of the Upper Eocene of Paris. Finally, *Cannophyllites*, of the latter beds, has been considered as an ally of the existing *Canna* among the *Marantaceæ*.

Order 6. Gynandræ.—The only fossils hitherto referred to the Orchids are the *Protorchis* and *Palæorchis*, of the Middle Eocene of Monte Bolca; and it is probable that the greater number of these plants, with their highly specialised and complexly perianthed flowers, are of comparatively recent origin.

Order 7. Helobiæ.—The last order comprises aquatic and marsh plants which date back to the Upper Cretaceous. *Laharpia*, from the Miocene of Œningen, may perhaps indicate a member of the *Jungaginaceæ* allied to the existing *Scheuchzeria*. In the *Alismaceæ* some of the forms, occurring from the Cretaceous upwards, referred to *Alisma* and *Sagittaria*, may be correctly named. *Butomus* has been recorded from the Miocene of Œningen. Of the *Hydrocharitaceæ*, *Stratiotes* and *Hydrocharis* have been described from Œningen, and the extinct *Hydrocharites* from the Miocene of Bonn; while *Valisneria* and *Ottelia* date from the Upper Eocene of the Paris basin in Europe, but the former also occurs in the Laramie of America, and thus carries back its origin to the Cretaceous.

Subclass II. Dicotylæ.—The Dicotyledons are plants having two cotyledons or seed-leaves, and the stems exogenous like those of the Gymnosperms. They represent the highest type of plant-life, their organisation being a great step in advance of the Monocotyledons. The earliest known members of this group occur in the reputed Lower Cretaceous of Greenland, where, however, only a

few forms are known; but when we come to the Dakota stage of the United States, which is usually correlated with the lower part of the Upper Cretaceous of Europe, Dicotyledons formed a large proportion of the flora, more than three hundred species having been described in 1885, which belong to both sections of the subclass. This abundance of forms pointing to the conclusion that the origin of Dicotyledons must be looked for in considerably earlier epochs.

Very different views are held by authorities as to the classification of Dicotyledons, some dividing them into several primary groups, while others only admit the three divisions Apetalæ, Polypetalæ, and Gamopetalæ. Dr Endlicher, however, makes only two divisions—Choripetalæ and Sympetalæ,—and since this arrangement is adopted by Dr Schenk in his 'Palæophytologie,' it will be followed in this work.

The larger proportion of the Cretaceous and Eocene Dicotyledons belong to the Choripetalæ, and especially to those orders in which the flowers are fertilised merely by the agency of the wind; the more specialised Sympetalæ, which require the aid of insects for this purpose being in great part of later date. The labours of Baron von Ettingshausen have shown that the Cretaceous and early Tertiary Dicotyledonous (and also the Monocotyledonous and Gymnospermous) flora was almost similar throughout the world; and that its present division into provinces is in great part due to the influence of one or more glacial periods. Bearing in mind this world-wide distribution of so many of the genera, it will be unnecessary in most cases to do more than mention their earliest established occurrence; and owing to the immense number of families only the more important types can be even mentioned at all. Space will not permit any reference to the gradual differentiation of the existing floras, or to the interesting distribution of modern arctic types in the Pleistocene, for which the reader must refer to the works of Baron von Ettingshausen, Sir J. W. Dawson, and other writers. It should be mentioned that in the case of trees known only by the leaves the generic determination may be open to doubt in some cases.

Division A. Choripetalæ.—This large group is characterised by the petals being either absent, or if present not united together.

Order 1. Amentaceæ.—This order comprises trees which are typically apetalous with the male flowers in the form of catkins. It includes five families, and comprises some of the earliest known representatives of the subclass. The first family, *Casuarinidæ*, is now represented only by the well-known *Casuarina* of the Australian and the eastern Malayan regions: this genus apparently occurs in the Lower Tertiary of Sumatra, but it is very improbable that the Euro-

pean fossils described under this name are really referable to the group. With the *Cupuliferæ*, containing the Alders, Birches, Hazels, Beeches, Oaks, &c., we come to a large group well represented in a fossil state, many of the forms being known by the seeds as well as the leaves. The existing genera *Alnus* (Alder), and *Betula* (Birch), are recorded from the Laramie and Dakota stages of the Upper

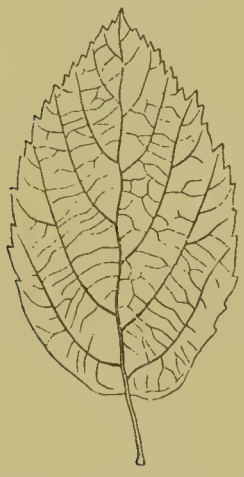


Fig. 1407.—Leaf of *Alnus gracilis;* from the Miocene of Europe. (After Unger.)



Fig. 1408.—Leaf of *Betula cuspidens*, and fruit of *B. dryadum;* from the Lower Miocene of Europe. Reduced. (After Saporta and Brongniart.)

Cretaceous of the United States, and likewise from the Cretaceous of Greenland, but Dr Schenk suggests some doubt as to whether these forms really belong to the living genera, and would prefer to call them *Alnophyllum* and *Betulophyllum*. An allied Cretaceous form has been named *Alnites*. In the Tertiary the existing genera (figs. 1407, 1408) are well represented from the Eocene upwards. In the next subgroup *Corylus* (Hazel), *Ostrya*, and *Carpinus* (Horn-



Fig. 1409.—Leaf of *Dryophyllum;* from the Lower Eocene of Europe. Reduced. (After Saporta.)

beam) also occur from the Eocene, while the former is recorded from the Laramie. *Fagus* (Beech) dates from the Dakota stage, which has also yielded remains referred to *Castanea* (Chestnut); and *Castanopsis* has been recorded from the American Eocene, and the Australian Tertiary, although it is suggested that some of the forms so named may belong to *Dryophyllum*. The latter name is applied

to elongated leaves (fig. 1409), from the Upper Cretaceous and Eocene of both Europe and North America, which appear to be in some respects intermediate between those of *Castanopsis* and the earlier species of Oaks. The leaves of *Quercus* (Oak) are subject to an enormous amount of variation, rendering the determination of fossil forms a work of extraordinary difficulty. One of the most ordinary and characteristic types of leaf is shown in fig. 1410, but in the early Tertiary and Upper Cretaceous we meet with long slender oak-leaves approximating to those of *Castanea* in general contour. The earliest recorded occurrence of the genus is in the Dakota stage, and it is abundantly represented throughout the Tertiaries; leaves, from the Tertiary of Australia, in which country oaks are now absent, have been described as *Quercus*, but doubt has been thrown on this determination. In the *Juglandaceæ*, the genus *Juglans* (Walnut) probably dates from the Upper Cretaceous of America and Greenland; the Tertiary species of which a leaf is figured in the woodcut occurs on both sides of the Atlantic, and appears to be closely allied to the existing *J. regia*. The name *Juglandites* has been applied to leaves from the Upper Cretaceous and Eocene of Europe, which are believed to indicate an allied type. *Carya* (Hickory), now confined to America, is recorded from the Cretaceous of that country, and occurs in both the European and American Tertiaries. Similarly the Old World *Pterocarya* is represented in the Tertiaries of both hemispheres, while the Oriental genus *Engelhardtia* occurs in the Upper Eocene of Aix, where it has been described as *Palæocarya*. In the *Myricaceæ* the single genus *Myrica* makes its first appearance in the Upper Cretaceous of Greenland and North America, and is common in the Tertiaries. Of more palæontological importance is the family *Salicaceæ*, in which both *Populus* (Poplar) and *Salix* (Willow), (fig. 1415, *d*), date from the Upper Cretaceous. A leaf from beds at Komi in Greenland, which have been regarded as Lower Cretaceous, has, indeed, been described as *Populus*, but according to Mr J. S. Gardner on totally insufficient grounds; but Sir J. W. Dawson considers that *Salix*



Fig. 1410.—Leaf of *Quercus conferta*. Recent. Reduced. (After Schenk.)

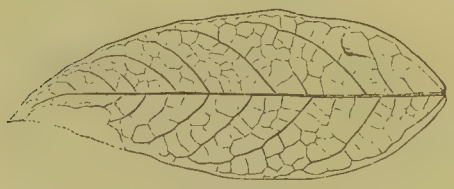


Fig. 1411.—Leaf of *Juglans acuminata*; from the Miocene of Europe. Reduced. (After Schenk.)

may occur in the Lower Cretaceous of the United States. The species of *Populus* of which a leaf is figured in the woodcut extends from the Lower Miocene to the Pliocene.



Fig. 1412.—Leaf of *Populus latior*: from the Miocene of Europe. Reduced. (After Schenk.)

Order 2. Urticinæ.—This order contains the three families *Ulmaceæ*, *Urticaceæ*, and *Ceratophyleæ*; the last of which requires no further mention. In the first family *Ulmus* (Elm) makes its first undoubted appearance in the Upper Eocene (Lower Oligocene) of Aix, in Provence, but the Asiatic and American *Planera* dates from the Laramie Cretaceous, and is common in the European Tertiary. *Celtis* (Nettle-tree), now abundant in southern Europe, is well represented throughout the Continental Miocene; while *Morus* (Mulberry) is unknown before the Upper Miocene. The tropical *Artocarpus* (Bread-fruit) dates from the Upper Cretaceous of Greenland, and also occurs in the Œningen Miocene; and it is probable that some of the forms from the Lower Eocene and Miocene of Europe described under the names *Artiocarpidium* and *Artiocarpoides* are allied types, although others belong to *Ficus*. The latter genus includes the numerous species of Fig mostly characteristic of the warmer regions; it dates from the Greenland Cretaceous and the Laramie, and is abundant in the Tertiaries of many parts of the globe. The names *Ficonium* and *Protoficus* have been applied to fig-like leaves from the Eocene, some of which may belong to this family. In the *Urticaceæ* it has been considered that *Urtica* (Nettle) occurs in the Middle Miocene of Styria, but this requires confirmation. That the family occurred in the Tertiary is, however, proved by the genus *Forskohleanthemum*, which is found in amber, and is allied to the existing tropical and subtropical genus *Forskohlea*. Here may be mentioned certain genera of uncertain affinity which are considered by Dr Schenk to be allied to the *Urticaceæ*, although Sir J. W. Dawson would place them near the *Platanaceæ*; these comprise the Upper Cretaceous *Credneria* and *Ettingshausia* from Europe; *Macclintockia*, with more elongated leaves, from both the Cretaceous and Eocene; and *Protophyllum* of the American Cretaceous, which is considered by Dr Schenk to be allied to the existing Urticaceous genus *Laportea*.

Order 3. Piperineæ.—In this group *Piper* (Pepper) and allied forms described as *Piperites* occur in the Lower Tertiary of Java and Sumatra; the existing forms being now tropical.

Order 4. Centrospermæ.—This large order, which includes the

Pinks and Portulacas, is very sparingly represented in a fossil state, but we may mention that *Polygonum*, *Coccolabis*, and *Salsola* occur in the European Miocene; while *Pisonia* is found in the Middle Tertiaries of both Europe and North America.

Order 5. Polycarpieæ.—Of the nine families constituting this order only the *Lauraceæ*, *Nymphæaceæ*, and *Magnoliaceæ* are of much importance to the palæontologist. In the *Lauraceæ* the existing genera *Laurus* (Laurel), *Sassafras* (fig. 1415, *a*) *Cinnamomum* (Cinnamon, fig. 1413), *Persea* (Alligator-pear, fig. 1414), and *Oreodaphne*, occur in the Upper Cretaceous of Europe or the United States, and throughout the greater part of the Tertiaries. With the exception of *Laurus* all these genera are now tropical or subtropical, *Persea* and *Oreodaphne* being restricted to America; and their abundance in the European Tertiaries affords conclusive proof of the warm climate of that epoch. *Cinnamomum* also occurs in the Tertiary of Australia, and *Litsæa* in that of Borneo. In the *Berberidaceæ* the type genus *Berberis* (Berberry) dates from the Lower Miocene; but with the *Menispermaceæ* we return to a family dating from the Cretaceous, where it is represented in the United States by the extinct *Menispermites*. *Cocculus*, of the Oriental region, is found in the European Pliocene, and has also been recorded from the Eocene, but the latter determination is doubtful. Leaving out some other unimportant types we may pass to the family *Magnoliaceæ*, which has a palæontological history of



Fig. 1413.—*Cinnamomum polymorphum*. *a*, Leaf; *b*, Flower; from the Upper Miocene of Europe. Reduced.



Fig. 1414.—Leaf of *Persea princeps*; from the Upper Miocene of Switzerland. Reduced. (After Heer.)

considerable interest. The type genus *Magnolia*, so well known for its magnificent white flowers, is now confined to Asia and North America, but in the Tertiary was spread over all Europe, and has also been recorded from Australia; its earliest appearance being in the Upper Cretaceous of France and the United States. The other well-known genus is *Liriodendron*, now represented only by the handsome Tulip-tree (*L. tulipifera*) of eastern America, but in former times having a wide distribution, and dating from the Cretaceous of

both hemispheres. The leaves (fig. 1415, *b*) are readily recognised by their lyre-like form and deep terminal emargination.

The observations of Dr Newberry on this genus are so interesting that, with some omissions and verbal alterations, they may be quoted at length. The doctor observes, "that a plant so splendid should stand alone in the vegetation of the present day excited the wonder of the earlier botanists, but the Sassafras, Sweet-gum, and the Sequoias of the West afford similar examples of isolation. Three species of *Liriodendron* occur in the Cretaceous of New Jersey, and others have been obtained from the Dakota group in the West, and from the Upper Cretaceous of



Fig. 1415.—Leaves of American Cretaceous Dicotyledons. *a*, *Sassafras cretaceum*; *b*, *Liriodendron Meeki*; *c*, *Leguminosites Marcouanus*; *d*, *Salix Meeki*. (After Dana and Lesquereux.)

Greenland. Though differing considerably among themselves in size and form, all these have the deep sinus of the upper extremity of the leaves so characteristic of the genus, and the venation is also essentially the same. Hence we must conclude that the genus, now represented by a single species, was in the Cretaceous age much more largely developed, having many species, and those scattered over many lands. In the Tertiary the genus continued to exist, but the species seem to have been reduced to one, which is hardly to be distinguished from that now living. In many parts of Europe leaves of the tulip-tree have been found, and it extended as far south as Italy. Three European species have, indeed,

been described, but they are all so like the living form that they should probably be united with it. We here have a striking illustration of the wide distribution of a species which has retained its characters both of fruit and leaf quite unchanged through long migrations and an enormous lapse of time. In Europe the tulip-tree, like many of its American associates, seems to have been destroyed by the cold of the glacial period, the Mediterranean cutting off its retreat; but in America it migrated southward, and returned northward with the amelioration of the climate."

The mainly tropical family of the *Anonaceæ* includes trees and shrubs closely allied to the Magnolias, and the existing American and Malayan genus *Anona* is represented in the Upper Cretaceous and Tertiary of the United States, while in Europe it is found from the Eocene to the Pliocene. The extra-tropical North American genus *Asimina* occurs in the Laramie and Eocene of the same regions. The large family of the *Ranunculaceæ* is sparingly represented in a fossil state; thus *Clematis* has been recorded from the reputed Pliocene of Japan, the Miocene of Œningen, and the Eocene of Croatia, but it is not absolutely certain that the determination is correct. The same remark applies to other Tertiary plants referred to *Ranunculus* and *Helleborus* (*Helleborites*). The names *Dewalquea* and *Debea* have been applied to Upper Cretaceous plants considered to belong to this family, although Dr Schenk suggests affinity with the *Aroideæ*. The Water-lilies of the family *Nymphæaceæ* date from the Upper Cretaceous, where we meet with remains of the existing genus *Nelumbium*, succeeded in the Upper Eocene (Oligocene) by *Nymphæa* (fig. 1416). Seeds from the Miocene of Germany, described as *Holopleura*, are considered to be allied to those of the celebrated *Victoria*, of the African lakes. Other Tertiary types have been referred to extinct genera under the names of *Anœctomeria*, *Nymphæites*, and *Carpolithes*. Finally, the genus *Nuphar* is unknown before the Norfolk Forest-bed, where we meet with the existing Yellow Water-lily.

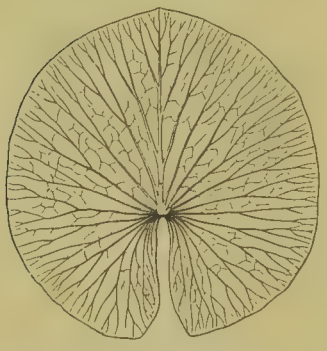


Fig. 1416.—Under surface of a leaf of *Nelumbium Dumasi*; from the Upper Eocene of France. One-eighth natural size. (After Saporta.)

Order 6. Rhoëdinæ.—Of the *Papaveraceæ* (Poppies) and *Cruciferæ*, constituting this order, the palæontological history is almost a blank, although a few Miocene forms have been referred to them. The *Cruciferæ* include the Cabbage tribe.

Order 7. Cistifloræ.—This order is of somewhat more palæontological importance. In the *Violaceæ* (Violets and Pansies), *Anchietea* is recorded from the Miocene of Auvergne; while in the

Cistaceæ (Rock-roses) a *Cistus* has been described from that of Germany. A *Kiggelaria*, from the Upper Eocene of Saxony, is the only fossil representative of the *Bixaceæ*. The tropical family *Ternstrœmiaceæ* is somewhat better known; thus we find *Pentaphylax* in amber of middle Tertiary age, while *Stuartia* also occurs in amber as well as in Pliocene beds. The genera *Ternstrœmia*, *Freziera*, and *Sauruja* are known as fossils only by their leaves; the first dating from the Cretaceous of Bohemia, the second from the Eocene, and the third from the Miocene. Another tropical family, the *Dipterocarpeæ*, is represented in the Eocene of Sumatra and Borneo by species of the genus *Dipterocarpus*, now inhabiting the same regions, and yielding the balsam of Copaiba.

Order 8. Columniferæ.—This order includes the four families *Tiliaceæ*, *Sterculiaceæ*, *Malvaceæ*, and *Bombaceæ*. In the first the existing genera *Tilia* (Lime), *Grewia*, and *Elæocarpus* occur fossil, the former dating from the Laramie, and the two latter from the Upper Eocene or Lower Miocene. Of extinct genera we may mention the Cretaceous and Lower Eocene *Grewiopsis* and *Apeibopsis*; the former being known by leaves, and the latter by gourd-like fruits, of very common occurrence in the London Clay, which resemble those of the existing American genus *Apeiba*. *Nordenskiœldia* is based on allied fruits from the Tertiary of Spitzbergen. The *Sterculiaceæ* is an exclusively tropical family of trees and shrubs, in which the existing genus *Sterculia* commences in the Dakota Cretaceous, and continues right through the European Tertiaries. Extinct genera are *Dombeyopsis*, *Pterospermites*, and *Fracastella*, all of which commence in the Cretaceous, and continue to the Lower or Middle Tertiary. The leaves of *Dombeyopsis* (fig. 1417) are acutely trilobate, with numerous veins. The *Malvaceæ* and *Bombaceæ* have left but little record of their past history; but *Bombax* occurs in the Upper Eocene of Europe.



Fig. 1417.—Under surface of a leaf of *Dombeyopsis Decheni*; from the Lower Miocene of Germany. One-fourth natural size. (After Schenk.)

Order 9. Gruinales. — The palæontology of this order, which includes Geraniums, Tropæolums, Sorels, Flax, and Balsams, may be summed up in very few words. It is thought that *Geranium* may occur in amber; the Tertiary *Oxalidites* is referred to the *Oxalidaceæ*; but the Tertiary fruit described

as *Linum* (flax) is of very doubtful value as evidence of the family *Linaceæ*.

Order 10. Terebinthinæ.—Of the families constituting this order, several are very imperfectly known before the present epoch. In the *Rutaceæ* (Rue-worts) the genus *Xanthoxylon*, which is now mainly tropical, occurs in the Upper Eocene and Lower Miocene of Europe, and also in the North American Tertiaries. *Ptelea* appears at the same date, but persists to the close of the Miocene period. With regard to *Protamyris*, from the Tertiary of Croatia, which was described as being allied to the existing *Amyris*, there is considerable doubt whether it really belongs to this family at all. In the *Simarubaceæ* the Indian and Chinese genus *Ailanthus* was formerly more widely spread, being found in Europe from the Upper Eocene to the Upper Miocene. There is some doubt whether the plants from the Middle Eocene of Monte Bolca, referred to the genus *Guajacites*, are really representatives of the American family *Zygophyllaceæ*. The large family of the *Anacardiaceæ*, typically represented by the tropical *Anacardium* (Cashew-tree), is known by a considerable number of fossil forms, although there is some doubt as to whether several of these are rightly determined. From the Upper Eocene of Provence a fruit has been referred to this family under the name of *Trilobium*. *Pistachia* (Pistachio), now distributed over the temperate zone of the northern hemisphere, is known from the European Upper Eocene and Miocene; while the name *Anacardites* has been given to leaves occurring from the Cretaceous to the Miocene. A large number of species, dating from the Upper Cretaceous and continuing through the Tertiaries of both Europe and America, have been referred to *Rhus* (Sumach), but it is probable that some of these belong to other plants. Of the other families, it will suffice to say that in the *Coriariaceæ* the genus *Coriaria* occurs from the Lower Miocene to the Pliocene of Europe.

Order 11. Æsculinæ.—In this order the family *Sapindaceæ*, with the exception of *Kœlreuteria*, *Staphylea*, and *Æsculus*, is now confined to the tropics, and includes trees of large size. Fruits from the London Clay termed *Cupanoides*, and others from the Miocene of Croatia described as *Cupanites*, are believed to have belonged to sapindaceous trees allied to *Cupania*. *Paullinia* has been recorded from the Middle Tertiaries of the Continent, while *Kœlreuteria* occurs in the Upper Miocene. Fruits from the Tertiary of Eubæa have been referred to *Nephelium*, while an imperfect leaf from Borneo probably belongs to the same genus. *Sapindus*, which in America does not range north of Texas, is abundantly represented in the Upper Cretaceous and Tertiaries of both the Old and New Worlds. *Æsculus* (Horse-chestnut) has been recorded from the Laramie beds, but in Europe appears to be unknown

before the Lower Miocene, although said to be abundant in the earlier Tertiaries of Japan. *Dodonæa*, now mainly confined to the southern hemispheres, is found in the Tertiaries of Europe and North America. Again, *Staphylea*, which is unknown as a fossil in Europe, is abundant in the Eocene of the United States. The genus *Acer* (Maple and Sycamore), now widely distributed, is represented by a great number of fossil species ranging from the Laramie stage upwards. The leaves are subject to great variation in form, the most remarkable types occurring in the Pliocene *A. polymorpha;* the woodcut shows a leaf of the more ordinary form together with one of the characteristic winged seeds.

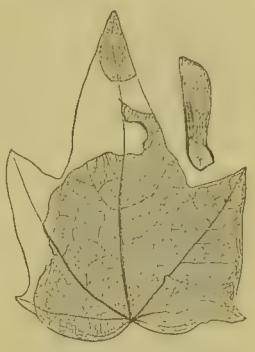


Fig. 1418.—Leaf and seed of *Acer acutilobata;* from the Miocene of Germany. One-third natural size. (After Schenk.)

The mainly tropical family *Malpighiaceæ* is represented in the Tertiary from the Upper Eocene to the higher Miocene by several existing genera, such as *Stigmaphyllum*, *Banisteria*, *Tetrapteris*, and *Hiræa*, together with the extinct *Malpighiastrum*, ranging from the Eocene to the Upper Miocene or Pliocene; the whole of the above-mentioned existing genera being now confined to America.

In this place we may mention the family *Platanaceæ* which is placed by some writers in the Amentaceæ or Urticinæ, but of which the ovary and the general appearance of the trees bring it near to the Maples and Sycamores. Of the single genus *Platanus* (fig. 1419) there is now one species in Asia Minor and another in North America; fossil forms occurring as low down as the Dakota Cretaceous and continuing through the Tertiaries of both hemispheres, their last appearance in Europe being in the Œningen Miocene.



Fig. 1419.—*Platanus aceroides*. *a*, Leaf; *b*, The core of a bundle of pericarps; *c*, A single fruit or pericarp, natural size. Upper Miocene.

Order 12. Frangulinæ.—Among the more important fossil forms found in this order we may mention that in the *Celastraceæ* *Euonomus* (Spindle-wood) makes its first known appearance in the Miocene by forms allied to Indian types; while *Celastrus* dates from the Cretaceous of Greenland, and is known by a host of Tertiary species. The two extinct genera *Celastrophyllum* and *Celastrinites* commence in the Upper Cretaceous, the one continuing to the Pliocene but the other unknown above the Eocene. Finally, remains from the Miocene of Styria have been referred to the South American

genus *Maytenus*. Whether the *Hippocrateaceæ* and *Pittosporeaceæ* occur fossil is uncertain, although Tertiary plants from Styria have been referred to *Hippocratea* and others from Provence to *Pittosporum*.

In the *Aquifoliaceæ* the genus *Ilex*, typically represented by the Holly, is abundantly represented throughout the Tertiaries, and is also recorded from the Cretaceous of both hemispheres, commencing in the Dakota stage. The extensive family of the *Rhamnaceæ* has afforded ample proof of its existence in earlier periods; thus the Old World genus *Paliurus*, and the tropical *Zizyphus* (Jujube) both date from the Cretaceous and persist in Europe till the Pliocene. In the Laramie Cretaceous and the European Tertiary we have the existing American genus *Berchemia;* while other plants from the Laramie have been made the types of an extinct genus *Rhamnites*. Finally, the genus *Rhamnus* (Buckthorn), mainly characteristic of the northern temperate zone, can be traced back to the Upper Cretaceous of the Old and New Worlds. The last family of this order is the *Vitaceæ*, in which we find *Cissus*, of the tropics, recorded from the Miocene of Croatia and elsewhere; allied Cretaceous forms described as *Cissites* and *Chondrophyllum;* while *Vitis* (Vine) itself is known to date as far back as the Laramie Cretaceous.

Order 13. Tricoccæ. — Of this order, which includes the *Euphorbiaceæ* (Spurges), *Buxaceæ* (Box), and *Empetraceæ*, the palæontological history is almost a blank; the first family being unknown in a fossil state, the second dating from the Pliocene, and the third from the Pleistocene.

Order 14. Umbellifloræ. — The occurrence of the typical family *Umbelliferæ*, of which Parsley is a well-known representative, in a fossil state is doubtful, but the other two families are commonly represented. Thus in the *Araliaceæ Panax* occurs in the Miocene, and has also been recorded from the Upper Cretaceous; while *Aralia* also dates from the same epoch and was abundant in the Eocene; and *Hedera* (Ivy) is first known from the early period of the Dakota stage. Finally, in the *Cornaceæ* the typical genus *Cornus* (Cornel) together with *Nyssa* make their appearance in the Upper Cretaceous.

Orders 15, Saxifraginæ; 16, Opuntinæ; 17, Passiflorinæ.— Of these three orders the second is totally unknown in a fossil state, while the only trace of the third (Passion-flowers) is afforded by some exceedingly doubtful leaves from the Oligocene. In the first, however, the family *Hamamelidaceæ* is represented in the European Miocene by species of the existing Asiatic genus *Parrotia*, and by the extinct *Hamamelites* of the Lower Eocene of Sézanne, while *Liquidambar* (Sweet-gum) dates from the Cretaceous of Europe and the United States, the Cretaceous species having the leaves with entire margins.

Order 18. Myrtifloræ.—In the *Onograceæ* the well-known genus *Trapa* (Water-chestnut), characterised by its peculiar spiked fruits and now confined to the Old World, makes its first known appearance in the Laramie Cretaceous of the United States, while in Europe it dates from the Upper Eocene (Lower Oligocene). Curiously enough *T. borealis* of the Tertiary of Alaska and the Laramie stage is allied to the existing Oriental *T. bispinosa*, and not to the four-spined European species; the writer has seen specimens from the Pliocene Siwaliks of Perim Island which probably belong to *T. bispinosa*. The family *Halorhagidaceæ* is not known before the Pleistocene; while there is only very doubtful evidence as to the occurrence of the *Combretaceæ*, *Lythrariaceæ*, and *Melastomaceæ* in a fossil state, although plants from the Eocene of Provence have been referred to *Terminalia* (*Combretaceæ*), and the name *Melastomites* has been applied to others from the Westphalian Cretaceous. In the *Myrtaceæ*, however, we have a large number of fossil forms; thus *Myrtus* (Myrtle) dates from the Upper Eocene of Provence, while an apparently allied Cretaceous type has received the name of *Myrtophyllum*. The genus *Metrosideros*, which includes several climbing species, and is now characteristic of the Moluccas and the Australasian region, appears to be represented in Europe from the Cretaceous to the Miocene; while *Eucalyptus* (Gum-tree), of Australia, occurs in the Laramie Cretaceous and the European Tertiaries. Finally, *Callistemophyllum* and *Leptospermites* are extinct European Tertiary types.

Order 19. Thymelinæ.—In the two families *Thymelæaceæ* and *Eleagnaceæ* the Australian genus *Pimelea* has been recorded from the Lower Tertiary of Europe and the United States, while *Daphne* is common in the European Tertiaries. A number of fossil forms have been referred to the large family *Proteaceæ*, but since at least in some cases the determinations are doubtful it will suffice to state that plants dating from the Eocene have been referred to the existing genera *Dryandra*, *Banksia*, *Knightia*, *Lomatia*, *Grevillea*, and *Persoonia;* while as extinct types we have the Cretaceous *Dryandroides*, and the Eocene *Banksites*, *Knightites*, *Embothrites*, *Lomatites*, &c.

Order 20. Rosifloræ.—This important order is not well represented in a fossil state, although in some genera a considerable number of species have been described. In the *Rosaceæ* the genus *Rosa* (Rose) appears to be represented by several Miocene species; while among the *Amygdalaceæ Prunus* (Plum) and *Amygdalus* (Almond) certainly date from the Miocene, and are perhaps of earlier origin. In the *Pomaceæ Pirus* (Pear) would likewise appear to occur in the Miocene, but the North American Cretaceous plant referred to this genus is probably different; while of other types *Amelianchier* (Medlar) has been recorded from the Tertiary of

Europe and the United States and also from the Laramie. *Cotoneaster* dates from the Eocene of Provence, and *Cratægus* (Thorn) from the Laramie.

Order 21. Leguminosæ.—The large and well-known order of Leguminous plants, in which the fruit is usually in the form of a pod or legume, in which the seeds are placed, is divided into three families, of which the palæontological history is still imperfect. In the *Papilionaceæ*, characterised by their imbricate papilionaceous petals, leaves from the Miocene of Croatia have been referred to the Australian genus *Gastrolobium*, but the determination is very doubtful; and the same remark applies to those described as *Oxylobium*. *Genista* (Broom) has been recorded from the Miocene of Germany; *Cytisus* from several European Miocene deposits; and *Trigonella*, *Indigofera* (Indigo), and *Tephrosia* from the Upper Miocene of Œningen. *Robinia* apparently dates from the Lower Miocene of Germany; while *Colutea* occurs at Œningen, and is also recorded from the Cretaceous of America and Greenland; and *Erythina* is represented in the Croatian Miocene. Passing by some less important forms we may notice that *Dalbergia*, now mainly confined to India, is common in the European Tertiaries, and is also recorded from the Cretaceous; while the American *Drepanocarpus* occurs in the Eocene of Monte Bolca, the Asiatic *Pterocarpus* in the Miocene, and the American *Piscidia* in the Miocene of Croatia. *Micropodium*, *Phascolites*, and *Ervites* are extinct types from the Upper Eocene of Provence; *Palæolobium*, of the European Miocene, being also extinct. Finally, *Cercis* (Judas-tree), now represented by only a few species in the northern hemisphere, of which one occurs in southern Europe, dates from the Laramie Cretaceous, and is abundant in the Tertiaries. In the *Cæsalpiniaceæ* the genus *Gleditschia*, now confined to North America and China, occurs in the European Miocene, while *Cæsalpinia* dates from the Eocene. The Upper Eocene of Provence has yielded an extinct type termed *Cæsalpinites*. The widely spread tropical and subtropical genus *Cassia* makes its first appearance in the Cretaceous of both hemispheres; *Bauhinia* occurs in the Miocene of Croatia and Œningen; and *Ceratonia* and *Copaifera* date from the Eocene. *Hymenæa*, of tropical America, is found in the Cretaceous of France and New Jersey; and the extinct *Podogonium* ranges from the Laramie Cretaceous to the Œningen Miocene. In the third family, or *Mimosaceæ*, *Prosopis* and *Inga* are described from the Eocene of Eubæa; while *Mimosa* and *Acacia* date from the Upper Eocene of Provence. In conclusion we have to mention the extinct genus *Leguminosites* (fig. 1415, *c*), ranging from the Cretaceous to the Miocene, of which the serial position is at present undetermined.

Order 22. Heterophylleæ.—With this order we come to the end of the Choripetalæ. In the *Aristolochiaceæ*, the type genus

Aristolochia, which includes climbing plants, usually having coloured sepals, dates from the Dakota Cretaceous, and also occurs in the European Miocene. The occurrence of fossil representatives of the *Santalaceæ* is open to some doubt; but remains attributed to the genera *Leptomeria*, *Osyris*, and *Santalum* have been described from the European Eocene and Miocene. The alleged occurrence of fossil representatives of the *Rafflesiaceæ* and *Balanophoraceæ* is too doubtful to need mention.

Division B. Sympetalæ.—With this second primary division of the Dicotyledons we reach the last and most specialised group of plants, characterised by the union of the lower part of the petals into a complete tube. These plants are dependent entirely, or to a great extent, upon the aid of insects for their fertilisation, and a large proportion of them are in all probability of comparatively modern origin. The group is frequently termed Gamopetalæ, and is divided into nine orders.

Order 1. Bicornes.—The family *Ericaceæ* is important from the effect which its massed foliage produces upon the landscape of many regions of the globe. Its type genus *Erica* (Heath), which is exclusively Old World, and very characteristic of the Cape, appears to be unknown before the Upper Miocene of Œningen; while *Andromeda* and *Leucothea* date from the Eocene. *Gaultheria* has likewise been traced back to the Eocene, in which period occur the extinct types described as *Andromedites* and *Arbutites*, and also a species referred to the existing genus *Arbutus*. The Rhododendrons, which some writers make the type of a distinct family, are represented by species of the widely-spread genus *Rhododendron* in the Eocene and Miocene, and by *Azalea* in the Miocene of Croatia and elsewhere. In the *Vacciniaceæ*, the type genus *Vaccinium* (Cranberry) is recorded from the Upper Eocene of Provence and higher deposits.

Order 2. Primulinæ.—In this order the subtropical and tropical genus *Myrsine*, the type of the family *Myrsiniaceæ*, is said to date from the Upper Cretaceous, and is well represented in the Eocene of Provence and the higher Tertiaries. *Myrsinites* is an extinct Tertiary type; and we also find in the Tertiary representatives of *Ardisia*, and some other forms of doubtful affinity.

Order 3. Diospyrinæ.—Coriaceous leaves, found in the Upper Cretaceous of Greenland and the United States, and also in the Lower and Middle Tertiaries, have been described under the name of *Sapotites* as being allied to the American and Australian genus *Sapota*, the type of the family *Sapotaceæ*. The existing American genus *Bumelia* occurs in the Green River Eocene of that country, and also in the Eocene of Provence and other Old World Tertiaries. *Achras*, which is likewise now exclusively American, has been described from the Croatian Miocene. In the *Ebenaceæ* the genus

Diospyros (Ebony), now mainly tropical, is represented by a few species in the Dakota and Greenland Cretaceous, is very abundant in the Upper Eocene of Provence, but has almost disappeared from Europe in the Miocene. Finally, in the *Styracaceæ*, the existing Asiatic and American genus *Symplocos* dates from the Lower Eocene of Europe.

Order 4. Contortæ.—In this order the *Gentianaceæ* (Gentians) are unknown before the Pleistocene. In the *Oleaceæ*, which includes most of the European trees belonging to the present division, *Olea* (Olive) makes its appearance in the Eocene of Provence; while the Australian genus *Notelæa* is recorded from the Eocene and Miocene of the Continent; and *Fraxinus* (Ash) occurs as far back as the Laramie Cretaceous. In the *Apocyanaceæ* we may mention *Nerium*, from the European Cretaceous and Tertiary, and *Tabernæmontana*, from the Eocene and Miocene; together with the extinct *Echitonium*, of the Eocene, and *Apocynophyllum*, of the Cretaceous and Tertiary.

Order 5. Tubifloræ.—In the Convolvulaceæ the tropical genus *Parana* occurs in the Upper Miocene of Œningen, and the somewhat older Tertiary of Croatia; while plants from the upper lignites of Winterhafen have been referred to *Convolvulus*. It is very doubtful if the *Asperifoliaceæ* are represented in a fossil condition, while the *Solanaceæ* (Night-shade, Potato, Tomato, Tobacco, &c.), are unknown.[1]

Order 6. Labiatifloræ.—The only family of this order of which we have any certain palæontological record is that of the *Bignoniaceæ*, in which we have representatives of the existing American genus *Catalpa* in the Laramie Cretaceous, and perhaps in the European Tertiaries. The occurrence of *Bignonia* in the latter is very doubtful.

Order 7. Campanulinæ.—This group, containing the Campanulas, Gourds, &c., seems to be unknown before the present epoch.

Order 8. Rubiïnæ.—In this order the *Rubiaceæ* are represented in the Miocene of Bonn by the extinct *Rubiacites;* and we have evidence of the existence of the handsome Asiatic and African genus *Gardenia* in the Miocene of Œningen and the Lower Eocene of the Soissonais. In the *Caprifoliaceæ*, the widely-spread genus *Viburnum* is represented by a number of species in the Laramie Cretaceous, and less commonly in the Tertiaries. The Miocene of Œningen has yielded remains of *Lonicera.*

Suborder 8. Aggregatæ.—With the specialised *Compositæ* we come to the end of our brief survey of the palæontological history of the Vegetable Kingdom. These plants are characterised by the

[1] The Eocene *Solanites* does not belong to this family.

collection of the small separate flowers in a common receptacle, the peripheral florets being modified into strap-like rays surrounding the fertile flowers of the disk. All the fossil forms have been referred to extinct genera, and include *Parthenites* and *Cypselites*, of the Upper Eocene of Provence; *Bidentites*, from the Upper Miocene of Œningen; *Hyoserites*, from the Tertiary of Priesen; *Hieracites*, from Provence; and *Silphidium*, from the Tertiary of Chiavon, which is supposed to be allied to the existing *Silphium*.

In this place it may be well to mention certain flowers from the Amboy Clays of New Jersey—the equivalents of the Dakota Cretaceous—which have been described under the name of *Palæanthus*, and are stated to present resemblances to those of the *Compositæ*. Dr Newberry observes, however, that "though these flowers so much resemble those of the *Compositæ*, we are not yet warranted in asserting that such is certainly their character."

LITERATURE.

The subjoined list comprises only a very limited selection from the great series of works and memoirs dealing with the subject of Palæobotany. The student desirous of fuller information as to the sources of knowledge as to fossil plants should consult the "Literaturverzeichniss" given by Count Solms-Laubach in his "Einleitung in die Paläophytologie" and the complete bibliography of works treating of Palæozoic plants given by Mr Kidston in his "Catalogue of the Palæozoic Plants in the British Museum."

1. "Handbuch der Palæontologie." K. A. von Zittel. Abtheil. ii. "Palæophytologie," by W. Ph. Schimper and A. Schenk. 1879-1889.
2. "Einleitung in die Paläophytologie." Count Solms-Laubach. 1887.
3. "Traité de Paléontologie Végétale." W. Ph. Schimper. 1869-74.
4. "The Geological History of Plants" ('International Scientific Series'). J. W. Dawson. 1888.
5. "Cours de Botanique Fossile." Renault. 1881-85.
6. "Évolution du Règne Végétal." 'Cryptogams,' 1881. 'Phanerogams,' 1885. Saporta and Marion.
7. "Versuch einer Geschichte der Pflanzenwelt." Unger. 1852.
8. "Monographie der fossilen Coniferen. Göppert. 1850.
9. "Die Flora des Bernsteins." Göppert and Menge. 1883.
10. "Flora tertiaria Helvetiæ." O. Heer. 1855-56.
11. "Flora fossilis arctica." O. Heer. 1868-83.
12. "The Fossil Flora of Great Britain." Lindley and Hutton. 1831-37.
13. "The Fossil Flora of the Gondwana System." 'Palæontologia Indica.' Ser. ii., xi., xii. 1863-82. Ottokar Feistmantel. (*For other works by this author see Kidston's "Catalogue."*)
14. "Die Tertiärfloren der Oesterreichischen Monarchie." 'Abhandl. d. k. k. Reichsanstalt zu Wein.' 1855. C. von Ettingshausen.
15. "On the Fossil Flora of New Zealand." 'Geol. Mag.' 1877. Also "On the Tertiary Flora of Australia." *Ibid.* C. von Ettingshausen.
16. "Acadian Geology," 2d ed. 1868. J. W. Dawson.

17. "The Fossil Plants of the Devonian and Upper Silurian Formations of Canada." 'Mem. Geol. Survey of Canada.' 1871 and 1872. J. W. Dawson.
18. "Report on the Fossil Plants of the Lower Carboniferous and Millstone Grit Formations of Canada." 'Mem. Geol. Survey of Canada.' 1873. J. W. Dawson.
19. "Description of the Coal Flora of the Carboniferous Formation in Pennsylvania and throughout the United States." 'Reports of the 2d Geolog. Survey of Pennsylvania.' 1880 and 1884. L. Lesquereux.
20. "The Tertiary Flora of the Western Territories." 'Reports of the U.S. Geol. Survey of the Territories,' vol. vii., 1878. L. Lesquereux.
21. "Synopsis of the Fauna of the Laramie Group." 'Sixth Ann. Rep. of the U.S. Geol. Survey.' 1885. L. F. Ward.
22. "Flore Carbonifère du department de la Loire et du centre de la France." Grand' Eury. 1877.
23. "Die Versteinerungen der Steinkohlenformation in Sachsen." Geinitz. 1853.
24. "On the Organisation of the Fossil Plants of the Coal-Measures." 'Phil. Trans.,' 1871, 1872, 1873, 1874, 1876, 1877, 1878, 1880, 1881, 1883. W. C. Williamson.
25. "A Monograph on the Morphology and Histology of Stigmaria ficoides." 'Palæontographical Society.' 1887. W. C. Williamson.
26. "On Fossil Cycadean Stems from the Secondary Rocks of Britain." 'Trans. Linn. Soc.' 1868. W. Carruthers.
27. "On the History, Histological Structure, and Affinities of Nematophycus Logani, Carr. (Prototaxites Logani, Dawson), an Alga of Devonian Age." 'Monthly Microscopical Journ.' 1872. W. Carruthers.
28. "Catalogue of the Palæozoic Plants in the British Museum." 1886. R. Kidston.
29. "On the Fructification and Affinities of Archæopteris hibernica." 'Ann. and Mag. Nat. Hist.' 1888. R. Kidston.
30. "A Monograph of the British Eocene Flora." 'Palæontographical Society.' Vol. i. "Filices" (1879, 1880, and 1882), by J. S. Gardner and C. von Ettingshausen. Vol. ii. "Gymnospermæ" (1883, 1884, and 1885), by J. S. Gardner.
31. "On Mesozoic Angiosperms." 'Geol. Magazine.' 1886. J. S. Gardner.
32. "The Appearance and Development of Dicotyledons in Time." *Ibid.* 1887. J. S. Gardner.
33. "Observations sur les Algues calcaires appartenant au groupe des Siphonées verticillées et confondues avec les Foraminiféres." 'Comptes rendus,' tom. lxxxv., 1877. Munier-Chalmas.
34. "Die Sogenannten Nulliporen" (Lithothamnium und Dactylopora). 'Abhandl. der k. Bayerischen Akad. der Wiss.' Bd. XI. 1874.
35. "Zur Kenntniss fossiler Kalkalgen (Siphoneen)." 'Neues Jahrb. für Min. Geol. und Palæontologie.' 1880. Steinmann.
36. "Geologische Algenstudien." 'Jahrb. d. k. preuss. geol. Landesanstalt.' 1880. Bornemann.
37. "On the Fossil Flora of the Radstock Series of the Somerset and Bristol Coalfield." 'Trans. Roy. Soc. Edin.,' vol. xxxiii. 1888. A. C. Seward.
38. "Sketch of Palæobotany." 'Fifth Ann. Rep. of the U.S. Geol. Survey.' 1885. L. F. Ward.

APPENDIX

APPENDIX.

I. INVERTEBRATE ANIMALS.

Foraminifera.

Mr E. Wethered has shown ('Geol. Mag.,' May 1889) that forms of *Girvanella* (see p. 127) occur abundantly in some of the Jurassic limestones of Britain. Mr Wethered has also made the interesting observation that the spheres of some of the so-called "pisolites" of the Jurassic series are in reality formed by the growth of layers of *Girvanella* round a central nucleus, and are, therefore, not of the nature of ordinary oolitic grains.

Receptaculitidæ (p. 170).

The remarkable fossils which are grouped together under the name of *Receptaculitidæ* have recently formed the subject of an important investigation by Herr Rauff ('Zeitschr. d. Deutschen Geol. Gesellschaft,' Bd. XL.) The following are the principal general conclusions at which this observer has arrived:—

1. The *Receptaculitidæ* are spherical or pyriform bodies, with a central closed cavity, the supposed basin-shaped examples being only fragments of the base.

2. Each of the individual spicular elements forming the wall of the body is composed of six parts—viz., an external plate of an essentially rhombic form, four diagonally intersecting tangential arms which lie immediately below the outer plate, and a radial arm or pillar which springs from the centre of the outer plate on its inner side, and is directed perpendicularly inwards.

3. An upper and lower pole may be distinguished on the exterior

surface, the arrangement of the plates at these points being peculiar. The basal pole (the starting-point of growth) is constituted by a circle of eight (or four) plates. The apical pole is closed by a variable, but always large, number of plates.

4. Each of the five arms of the skeletal elements or spicules is traversed by an axial canal, the canals of the four tangential arms having a conspicuously fusiform shape.

5. The radial arms or pillars terminate on the inner or "gastral" side in a conical dilatation, which is laterally extended till adjoining pillars touch. This internal thickening of the radial pillars is not furnished with a special plate, corresponding with the external plate, and is not penetrated by transverse canals.

6. The inner or "gastral" wall of the fossil is imperforate, the pores described by Billings being the result of fossilisation.

7. The genus *Ischadites* agrees essentially with *Receptaculites* in structure, but its skeletal elements are more slender. An apical aperture is in some cases clearly wanting in *Ischadites*, and probably did not exist at all.

8. The genus *Acanthochonia* is identical with *Ischadites*.

9. The geological range of *Ischadites* extends to the Upper Devonian.

10. The genus *Polygonosphærites* (*Sphærospongia*) is similarly constructed to *Receptaculites* as regards the tangential arms of the spicules, but the radial arms or pillars are wanting.

11. The *Receptaculitidæ* are not *siliceous* organisms, but the skeleton was originally *calcareous*, and the siliceous examples are the result of silicification. The group, therefore, cannot be referred to the Hexactinellid Sponges, and its systematic position is still entirely uncertain.

Mastopora and Cyclocrinus (p. 186).

In the memoir just referred to, Herr Rauff expresses the opinion that the genera *Mastopora* (*Nidulites*) and *Cyclocrinus* have no relationships with the *Receptaculitidæ*, but that they appear to be related to the *Polyzoa*.

Calcispongiæ (p. 178).

Some interesting discoveries as to the occurrence of Mesozoic Sponges have recently been made by Dr George J. Hinde, who has been good enough to furnish the following note of his investigations on this point: "In the Middle Lias of Northamptonshire (zone of *Ammonites spinatus*) some very minute Calcisponges have been lately discovered, with the same delicate structural characters as in the existing family of the *Leucones*, Haeckel, and they have even

been placed in the recent genus *Leucandra*, Haeckel. The largest of these fossil sponges is under 4 mm., or about one-sixth of an inch in height, and the spicules in their walls are as perfect as in recent specimens. A remarkable assemblage of small Calcisponges has also been discovered by Mr Walford in the Inferior Oolite (zone of *Ammonites Parkinsoni*) of Dorset. In their diminutive proportions they resemble living Calcisponges, but they all possess a structure of solid fibres, characteristic of *Pharetrones*. They mostly belong to the genera *Eudea*, *Peronella*, *Blastinia*, and to a new genus not yet described. Calcisponges of larger dimensions, belonging to *Peronella* and *Lymnorea*, are also abundant in the Inferior Oolite of Cheltenham. Certain zones of the Great Oolite in the neighbourhood of Bath are very rich in Calcisponges, principally of the genus *Peronella*. Higher up in the Oolitic series there is a well-marked zone of Calcisponges in the Lower Coral Rag of Yorkshire. They have mostly been hitherto placed in *Stellispongia;* species of *Peronella* and *Blastinia* are also present."

Stromatoporoidea (p. 229).

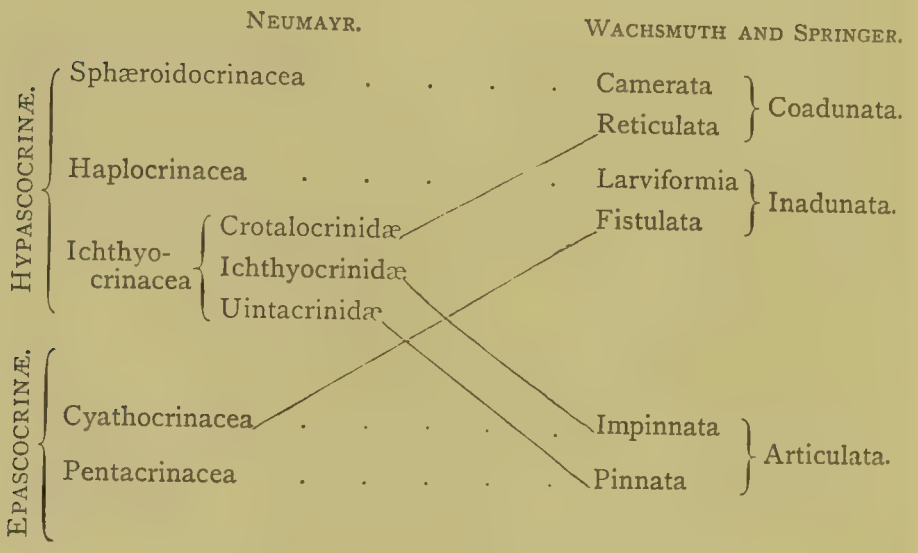
Since the earlier portion of the present work was written, the author has had the opportunity of studying the fasciculus of Dr Waagen's Monograph on the "Salt Range Fossils," which deals with the *Hydrozoa* ('Palæontologia Indica,' Ser. XII., No. 7, 1877). The most important point brought out in this memoir is, that the "Productus Limestone" of the Salt Range of India, the age of which is Permo-Carboniferous, contains various *Hydrozoa* which are more or less closely related to *Stromatopora* proper. For these the new genera *Disjectopora*, *Circopora*, *Carterina*, and *Irregulatopora* are proposed; but it would be impossible to make the structure of these intelligible without illustrations. It may, however, be considered as proved that the geological range of the Stromatoporoids, as a group, has by these researches been extended into the beginning of the Permian period; the latest undoubted types of the group previously known being Upper Devonian.

Dr Waagen, further, deals at some length with the general structure and zoological affinities of the Stromatoporoids. He divides them into two families, and refers them to the *Hydrocorallinæ*. It is unnecessary, however, to discuss Dr Waagen's views on these subjects here; since the conclusions which he has reached would probably have been more or less modified had he been acquainted with the previously published "Monograph on the British Stromatoporoids" (Palæontographical Society, 1885) by the present writer, in the general introduction to which the same questions have been dealt with in considerable detail.

Classification of the Crinoidea (p. 445).

Dr P. Herbert Carpenter has kindly supplied the author with the following note as to the classification of the Crinoids proposed by Neumayr in his recently published important work "Die Stämme des Thierreichs": "The new classification of the *Crinoidea* proposed by Neumayr is primarily based upon the condition of the mouth and ambulacra. These are either subtegminal (*Hypascocrinæ*) or free and exposed upon the ventral surface (*Epascocrinæ*). The first-named group includes all the Palæocrinoids, except *Cyathocrinus* and its allies (Families 12–20), which have been already distinguished as *Fistulata* by Wachsmuth and Springer. It has also been shown by these authors that some of the *Ichthyocrinidæ*, at any rate, had an exposed mouth and open ambulacra (see p. 431); so that this family can find no place in the *Hypascocrinæ*. Except, too, for having a subtegminal mouth, the *Haplocrinidæ* and their allies (*Larviformia*) seem to be more closely allied to the *Fistulata* than to the other Palæocrinoids (*Camerata*)."

The general relations of Neumayr's classification to that proposed by Wachsmuth and Springer may be seen in the following table:—



Cystoidea (p. 447).

An important posthumous work by M. Joachim Barrande on the Cystideans of Bohemia has recently been published, and Dr P. Herbert Carpenter has been good enough to furnish the author with the following note as to its contents:—

"This elaborate work contains descriptions of a large number

of new Cystideans from the Lower Palæozoic rocks of Bohemia. Some valuable morphological observations are also recorded therein; but most of them refer to questions of too complex a nature for discussion here. One point, however, must be noticed. In the new genus *Aristocystites* and in some half-dozen others Barrande describes the calcareous plates of the test as covered by a smooth 'external epidermis' which completely closes the openings of the pore-canals that penetrate the substance of the plates. This epidermis is very thin, not more than $\frac{1}{100}$ part of an inch in *Proteocystites*, and is therefore but rarely preserved to any great extent. The pores are sometimes isolated (haplopores), or a pair may be linked by a horse-shoe-shaped groove, or open together in a small oval depression, the 'oscule,' the whole structure being commonly known as a 'diplopore.' It was the resemblance of these diplopores to the groups of twin ambulacral pores in the Ordovician Sea-Urchin *Bothriocidaris*, which led Lovén to point out that the old theory of the connection of the diplopores of the Cystideans with the ambulacral system might after all be correct. This view, however, will have to be abandoned altogether if the pores really are closed by the external epidermis in the manner described by Barrande. But there is some doubt as to whether the appearances described by him may not be capable of a different interpretation, more especially as he suggests in one place that the pores may have been connected with tube-feet like those of the Urchins, while in another he notices their similarity to the respiratory pores of the Asterids which give passage to the gills or papulæ. But neither of these explanations could be possible if the pores really are closed as he describes.

"Neumayr, believing Müller's classification of the Cystidea according to the characters of their pores to be no longer a practicable one, has recently proposed the following scheme, which may be adopted until a fuller morphological knowledge of the group has provided us with the materials for a better one.

"I. Order Sphæronitidæ.—Test composed of numerous irregularly disposed plates, which may be aporous or bear haplopores or diplopores, but never rhombs. Five ambulacra, sometimes terminating in feebly developed arms. Generally sessile, but sometimes free or stalked.

"*Family* 1. *Sphæronitinæ.*—Ambulacra superficial and branching. *Sphæronites*, *Glyptosphærites*, *Eucystis*, *Proteocystites*, *Protocrinus*.

"*Family* 2. *Aristocystinæ.* Ambulacra subtegminal and branching. *Aristocystites*, *Pyrocystites*, *Craterina*.

"*Family* 3. *Mesitinæ.* Ambulacra superficial and simple. *Mesites*, *Agelacrinus*, *Edrioaster*, *Cytaster*, *Hemicystites*.

"II. Order Echinosphæritidæ.—Test composed of numerous rhombiferous plates; often with only three ambulacra, and slightly

developed arms. Sessile or stalked. *Echinosphærites*, *Dendrocystites*, *Caryocystites*, *Arachnocystites*.

"III. Order Pleurocystidæ.—Test shortly stalked and asymmetrical, the plates of the two sides being differently arranged except in the oldest genera (*Trochocystites*). Arms few and small. *Pleurocystites*, *Ateleocystites*, *Balanocystites*, *Mitrocystites*.

"The above scheme takes no account of such types as *Caryocrinus*, *Porocrinus*, *Echinoencrinus*, *Lepadocrinus*, *Callocystites*, and several other forms in which the plates of the test are few in number, with a more or less regular arrangement as in the Crinoids; while in *Cystoblastus* and *Asteroblastus* there is a calyx very similar to that of the Blastoidea. Most of these genera have hydrospires, either generally distributed on the calyx plates (*Caryocrinus*), or limited to a few of them as in *Echinoencrinus*, while *Asteroblastus* has diplopores.

"As at present constituted the class of the Cystidea is an extremely heterogeneous one, and much further investigation will be necessary before anything like a natural classification of the group becomes at all possible."

Bactrites (p. 846).

According to the observations of Branco ('Zeitschr. d. Deutschen Geol. Gesellschaft,' Bd. XXXVII., 1885), the initial chamber of the shell of *Bactrites* is an ovoid and dilated sac, similar to that of the shell of the Ammonoids and of *Spirula*. The genus *Bactrites* must therefore be removed to the *Ammonoidea*. According to the views of Branco, the genus should be ranked with the *Goniatitidæ*, the particular group of these to which it is referable occupying an intermediate position, as regards the form of the initial chamber, between the *Ammonitidæ* and the *Belemnitidæ*.

II. VERTEBRATA.

Pisces.

Chimeroidei.—As is mentioned in the Addenda, Mr Smith Woodward has recently made the genus *Myriacanthus* (p. 951) the type of the family *Myriacanthidæ*, which is defined as follows: Body elongated; anterior dorsal fin placed above the pectoral, and furnished with a long, straight spine. Teeth forming two or three pairs of thin dental plates in the upper jaw, the hinder pair alternated and not closely approximated in the middle line; lower teeth consisting of a pair of large dental plates meeting at the symphysis, and a median incisor-like tooth in front. A few dermal plates on the head; and a long prehensile spine upon the muzzle of the male.

Incertæ sedis.—Remains of a fish from the Oxford Clay of Peterborough have been described as *Leedsichthys*,[1] which apparently indicates the largest Jurassic representative of the class, although its serial position cannot yet be determined. A bone which is regarded as the frontal has a length of 24 inches, while the squamous hyomandibular is at least 15 inches long. The most remarkable features of this fish are, however, shown in the pectoral fin-rays, which sometimes attain a length of 5 feet, and frequently branch in a forked manner, but are not jointed. Each ray consists of fibrous bone, and appears to be composed of a number of long and tapering splints which are incompletely fused together, and the two halves of the ray remain separate.

Reptilia.

Anomodontia.—The author's recent study of the Anomodont remains in the British Museum has enabled him to make some amendments on the characters of the families and genera given in the text.

In *Tapinocephalus* (pp. 1057-58) the dentition, although it may have been of a carnivorous type, was not differentiated into incisives, tusks, and cheek-teeth; and it is highly probable that there were no secondary nares. It does not appear by any means certain that the one tooth on which the genus *Glaridodon* (p. 1061) is founded, is really distinct from *Titanosuchus* (p. 1058).

In the *Galesauridæ* (pp. 1058-59) the single narial aperture of the type specimen of *Ælurosaurus* is due to imperfection; and it is probable that the same is the case with *Cynodraco*, *Cynochampsa*, and *Cynosuchus*.[2] The latter has 7 or 8 cheek-teeth, with a posterior basal cusp, but the incisive and cheek-teeth appear to have no serrations on the posterior edge. *Cynochampsa* was probably allied, having $\frac{4}{3}$ incisive teeth as in *Cynosuchus*. In *Cynodraco* and the type of *Ælurosaurus* there are $\frac{5}{4}$ incisive teeth; and the crowns of the incisive and cheek-teeth have serrated posterior edges; and it has yet to be proved that *Ælurosaurus* is generically distinct from *Cynodraco*. In *Tigrisuchus* there are three pairs of upper incisive teeth.

Gorgonops (p. 1059) differs from the *Galesauridæ* in having the temporal fossæ roofed over, and apparently in the absence of second-

[1] The practice of making such barbarous compounds as *Leedsichthys*, *Oweniasuchus* (p. 1191), and *Wardichthys* (p. 979), is much to be deprecated. If a change be permissible, the terms *Leedsia* and *Wardia* may be suggested in place of the first and third of these uncouth names.

[2] By an error (see Corrigenda) these three genera are stated to have double nares, while in *Tigrisuchus* the nares are said to be single.

ary posterior nares. Roofed temporal fossæ also occur in the American genus *Chilonyx* (p. 1060); so that both of these forms approximate in this respect to the Pariasauria, although distinguished from the typical representatives of that group by the absence of sculpture on the cranial bones. *Gorgonops* may be regarded as the type of the family *Gorgonopidæ*, with an uncertain serial position.

The genus *Embolophorus* (p. 1060) is the only one in which the articulation of the capitula of the ribs to the intercentra has yet been observed.

It appears that there is no justification for Eichwald's reference of the tooth represented in fig. 983 (p. 1062) to *Deuterosaurus* rather than to *Brithopus*; the former genus having been founded upon part of the vertebral column of a smaller reptile than the one to which the humerus of *Brithopus* belonged.

The vertebræ of the *Diadectidæ* (p. 1061) are distinguished by the presence of zygosphenal (hyposphenal) articulations; while the skull has no secondary posterior nares. *Empedias* differs from *Diadectes* by the absence of a tusk; while *Helodectes* is distinguished from both by the double row of cheek-teeth.

Sauropterygia.—It is stated on page 1077 that the genus *Cimoliosaurus* has no trace of an interclavicle; it has, however, been subsequently suggested that certain splint-like bones found with some skeletons of the Oxfordian representatives of this genus are really the last remnants of the interclavicle and clavicles; the interclavicle probably fitting into the notch shown between the ventral plates of the scapulæ in fig. 988 (p. 1069).

Chelonia.—In a recent paper Dr Baur states that in the skull of *Protostega* (p. 1089) the parietals were connected by vertical plates with the pterygoids, and he accordingly regards the *Protostegidæ* as less specialised than the *Dermochelyidæ*. If this reference be correct there will be evidence of a nearer affinity between the Athecata and Testudinata than has hitherto been supposed.

The same writer also doubts the Chelonian nature of the problematical *Psephoderma* (p. 1089), and suggests that it may be founded upon the dermal armour of *Nothosaurus*. This argument is supported by the absence of Chelonian bones in the Lettenkohle (Lower Keuper), where *Psephoderma* is not uncommon; but the absence of a dermal armour in the *Lariosauridæ*, so far as it goes, is against this view.

In the *Testudinidæ* the genus *Palæochelys* (p. 1108), as is well shown by a specimen from the Pliocene of Italy recently described as *Emys Portisi*, has some of the neural bones tetragonal and others octagonal, and is thereby more nearly allied to *Nicoria* and the land tortoises than to *Ocadia*. The so-called *Emys crassa*, of the Upper Eocene of Hampshire, is, therefore, referable to *Ocadia*.

INDEX.

GENERAL INTRODUCTION AND INVERTEBRATA.

Abyssal clay, 74.
Acantharia, 145, 146, 147.
Acantherpestes, 584.
Acanthoceras, 867, 868.
Acanthochonia, 173, 1564.
Acanthocladia, 628.
Acanthocladidæ, 627.
Acanthometra, 146.
Acanthoraphis, 163.
Acanthotelson, 561.
Acanthoteuthis, 881.
Acarida, 575.
Acasta, 499.
Acentrotremites, 464.
Acervularia, 269, 273, 286, 287.
Achatina, 812.
Achistrum, 406, 407.
Acicula, 786.
Aciculidæ, 786.
Acidaspidæ, 540.
Acidaspis, 539, 540.
Acmæa, 762.
Acorn-shells, 496, 497.
Acraspeda, 206.
Acrididæ, 597.
Acrocidaris, 382.
Acroculia, 764.
Acrosalenia, 380.
Acrothele, 652.
Acrotreta, 651, 652,
Acroura, 403.
Actæon, 801.
Actæonella, 801.
Actæonidæ, 800.
Actæonina, 801.
Actinacis, 310.
Actiniaria, 261, 263.
Actinidæ, 261.
Actinoceras, 839, 840.
Actinoceratidæ, 839.
Actinocrinidæ, 425.
Actinocrinus, 426.
Actinocystis, 286.
Actinodonta, 717.
Actinometra, 412, 443.
Actinomma, 149.
Actinostoma, 626.
Actinostroma, 232, 233.
Actinozoa, 240.
Adacna, 728.
Adelarthrosomata, 577.
Adelphoceras, 844.
Adesmacea, 744.
Æchmina, 508.
Æger, 563.
Æginidæ, 206.
Ægites, 559.
Æglina, 536, 537.
Æglinidæ, 537.
Ægoceras, 864.
Ægoceratidæ, 864.
Agaricocrinus, 426.
Agassizocrinus, 436, 437.
Agelacrinidæ, 452.
Agelacrinus, 452, 453.
Agnostidæ, 545.
Agnostus, 545.
Alaria, 789.
Alcyonacea, 326.
Alcyonaria, 256, 324.
Alcyonidæ, 326, 327.
Alcyonium, 326.
Alecto, 616.
Alectryonia, 695, 696.
Allagecrinus, 432.
Allionia, 443.
Allomorphina, 131.
Allopora, 225, 226, 227.
Allorisma, 749, 750.
Alveolaria, 620.
Alveolina, 126.
Alveolites, 315, 316.

Alveopora, 311.
Amaltheidæ, 862.
Amaltheus, 863.
Amauropsis, 779.
Amberleya, 776.
Ambonychia, 708.
Ametabolic Insects, 592.
Ammonites, 855, 856, 864.
Ammonoidea, 833, 848.
Amœbea, 110.
Amphidetus, 390.
Amphigenia, 672.
Amphihelia, 267.
Amphion, 536, 537.
Amphipoda, 556, 557.
Amphipora, 236.
Amphispongia, 176, 177.
Amphistegina, 134.
Amphoracrinus, 426.
Amplexopora, 356.
Amplexus, 295.
Ampullaria, 780.
Ampullina, 779.
Ampyx, 544, 545.
Anabacia, 304, 305.
Anabacidæ, 304.
Ananchytes, 389.
Ananchytidæ, 389.
Anaptychus, 851.
Anarthropoda, 468, 469.
Anastrophia, 672.
Anatifa, 502.
Anatifopsis, 501.
Anatina, 749.
Anatinacea, 748.
Anatinidæ, 748.
Anaulocidaris, 375, 377.
Ancillaria, 798.
Ancyloceras, 869, 870.
Ancylus, 814.
Angelina, 531, 532.
Anguillula, 469.
Animal Kingdom, classification of, 85, 87.
Anisocardia, 736.
Anisophyllum, 296.
Annelida, 470.
Annulosa, 468.
Anodon, 721.
Anodonta, 721.
Anodontopsis, 724.
Anomalocrinidæ, 434.
Anomalocrinus, 434.
Anomalocystites, 452.
Anomia, 697.
Anomiidæ, 697.
Anomocladina, 165.
Anomura, 562, 565.
Anoplotheca, 664.
Anoplura, 592.
Anopolenus, 529.
Antedon, 409, 410, 411, 443.
Anthocrinus, 431.
Anthracitic Shales, 35.
Anthracomarti, 575.
Anthracomartus, 576.
Anthracomya, 751.
Anthracoptera, 711.
Anthracoscorpii, 579
Anthracosia, 722.
Anthrapalæmon, 563.
Antipatharia, 261, 263.
Antipathidæ, 244, 261, 263.
Ant-lions, 598.
Ants, 600.
Aphanaia, 706.
Aphaniptera, 599.
Aphis, 596.
Aphragmites, 843.
Aphrocallistes, 176.
Apiocrinidæ, 440.
Apiocrinus, 440.
Apiocystites, 456.
Aplysia, 802.
Aplysiadæ, 802.
Aporosa, 264, 265.
Aporrhaidæ, 789.
Aporrhais, 789.
Apterous Insects, 592.
Aptychopsis, 515.
Aptychus, 851, 852.
Apus, 510.
Apygia, 655.
Aqueous rocks, 11.
Arabellites, 480.
Arachnida, 572.
Arachnophyllum, 286, 287.
Arœopoma, 299, 301.
Arœopora, 309, 311.
Aragonite, in calcareous organisms, 25, 26.
Araneida, 580.
Arca, 712.
Arcacea, 712.
Arcestes, 856.
Arcestidæ, 855, 856.
Archædiscus, 135.
Archæocidaris, 376, 377.
Archæocyathinæ, 183, 185, 186.
Archæocyathus, 183, 184.
Archæolepas, 502.
Archæoniscus, 559.
Archæoscyphia, 166.
Archæosphærina, 143.
Archæozonites, 812.
Archanodonta, 721.
Archidesmus, 584.
Archimedes, 626, 627.
Archimedopora, 626.
Archimylacris, 593.
Archipolypoda, 582, 583.
Architarbus, 576.
Archiulidæ, 584.
Archiulus, 584, 585.
Arcidæ, 712.
Arcomya, 748.
Arcomyidæ, 748.
Arcturus, 558.
Arcia, 537.
Arenicolites, 481, 482.
Arethusina, 542.
Argiope, 676.

Argiopidæ, 675.
Argonauta, 881.
Arietites, 848, 864.
Arionellus, 531.
Aristozoë, 514, 515.
Armadillo, 559.
Artemia, 510.
Artemis, 737.
Arthrolycosa, 576.
Arthropleura, 559.
Arthropoda, 468, 491.
Arthropomata, 655.
Articulata (*Brachiopoda*), 655; (*Crinoidea*), 423, 424, 438, 446.
Asaphidæ, 533.
Asaphus, 520, 521, 522, 533, 534, 535.
Ascetta, 179.
Ascoceras, 841, 842, 843.
Ascoceratidæ, 841.
Ascodictyon, 613.
Ascones, 179.
Asiphonate Lamellibranchs, 691, 692, 693.
Aspergillum, 752.
Aspidocaris, 516.
Aspidoceras, 868.
Aspidosoma, 397.
Aspidura, 403, 404.
Assiminea, 781.
Astacus, 565.
Astarte, 724, 725.
Astartella, 725.
Astartidæ, 724.
Asteractinella, 177, 178.
Asterias, 391, 397, 398, 399.
Asteroidea, 391.
Asthenosoma, 380.
Astræidæ, 269-274.
Astræopora, 310.
Astræospongia, 177.
Astralium, 775.
Astrangia, 270.
Astrocrinidæ, 464.
Astrocrinus, 464.
Astrogonium, 397, 398.
Astroides, 241, 242.
Astromma, 149.
Astropecten, 392, 397, 398.
Astrophyton, 402.
Astrorhiza, 126.
Astrorhizidæ, 126.
Astylocrinidæ, 436.
Astylocrinus, 436, 437.
Astylospongia, 165, 166, 167.
Atelecrinus, 443.
Ateleocystites, 452.
Athyris, 666.
Atlanta, 803.
Atlantidæ, 802, 803.
Atractites, 878.
Atractosella, 162.
Atrypa, 668, 669.
Atrypidæ, 668.
Aturia, 846.
Aucella, 706.
Aulacoceras, 877.
Aulocopium, 165.
Aulophyllum, 292.
Aulopora, 255, 342.
Auloporidæ, 342, 343.
Aulosteges, 657.
Auricula, 813.
Auriculidæ, 813.
Avicula, 703.
Aviculidæ, 702.
Aviculopecten, 701, 702.
Aviculopinna, 709, 710.
Axinella, 162, 163.
Axinus, 720, 747.
Axophyllum, 293.
Axopora, 225.

Bactrites, 846, 1568.
Bactritidæ, 846.
Bactropus, 514.
Bactrynium, 678.
Baculites, 859, 861, 862.
Baerocrinus, 434.
Bairdia, 509.
Bakewellia, 705.
Balanidæ, 497, 499.
Balanophyllia, 308.
Balanus, 498, 499.
Barbados earth, 33, 148.
Barnacles, 500.
Barrandeocrinidæ, 427.
Barrandeocrinus, 427.
Barycrinus, 435.
Baryhelia, 267.
Baryphyllum, 296.
Baseopsis, 597.
Basommatophora, 813.
Bathmoceras, 847.
Bathycrinus, 441.
Bathyurellus, 532.
Bathyurus, 532.
Batocrinus, 426.
Battersbyia, 269, 271.
Beatricea, 233, 234.
Beekite, 7.
Belemnitella, 877.
Belemnites, 875, 876, 877.
Belemnitidæ, 874, 875.
Belemnocrinidæ, 434.
Belemnocrinus, 434.
Belemnosis, 878.
Belemnoteuthidæ, 878.
Belemnoteuthis, 879.
Belinurus, 548, 550.
Bellerophina, 769.
Bellerophon, 768, 769.
Bellerophontidæ, 768.
Beloptera, 878.
Belosepia, 880.
Beloteuthis, 880.
Berenicea, 618.
Beyrichia, 506, 507.
Bidiastopora, 617, 618.
Biflustra, 635.
Bifrontia, 772.
Bigenerina, 130.
Biloculina, 124.

Bimeria, 196, 197.
Bithynia, 780.
Bittium, 789.
Bivalve Molluscs, 683.
Blastoidea, 457.
Bohemilla, 532.
Bohemillidæ, 532.
Bolboporites, 364, 393.
Bolidium, 167.
Bopyridæ, 558.
Bothriocidaridæ, 374.
Bothriocidaris, 373, 374, 375.
Bothroconis, 173.
Bouchardia, 675.
Bourgueticrinidæ, 441.
Bourgueticrinus, 441.
Brachiopoda, 640.
Brachymetopus, 543.
Brachypyge, 566.
Brachytrema, 793.
Brachyura, 562, 566.
Branchiogastropoda, 760.
Branchipodites, 512.
Branchipus, 512.
Branchipusites, 512.
Breyeria, 594.
Briareum, 327.
Briarocrinus, 427.
Brisinga, 397.
Brissopsis, 390.
Brissus, 390.
Bronteidæ, 540.
Bronteus, 540.
Bryozoa, 604.
Bucania, 769.
Buccinidæ, 793.
Buccinum, 793.
Buchiceras, 863.
Bulimina, 130.
Bulimulus, 812.
Bulimus, 812.
Bulla, 801.
Bullidæ, 801.
Bumastus, 520, 536.
Bunodes, 549.
Buprestidæ, 600.
Burrows of Annelides, 481.
Buthograptus, 205.
Buthus, 574.
Byssocardium, 728.

Caddis-flies, 598.
Cadulus, 820.
Cæcidæ, 783.
Cæcum, 783.
Calamopora, 313.
Calapœcia, 306, 317.
Calathium, 166.
Calcareous rocks, 15.
Calcareous Sponges, 178.
Calcarina, 116, 117, 133, 134.
Calceocrinidæ, 437.
Calceocrinus, 437.
Calceola, 301.
Calceolidæ, 299.
Calcisphæra, 147.
Calcispongiæ, 178, 1564.
Calcite, in calcareous organisms, 25, 26.
Callianassa, 565.
Callicrinus, 430.
Callizoë, 514.
Callocystites, 449, 457.
Callodictyon, 176.
Callodictyonidæ, 176.
Callograptus, 205.
Callonema, 782.
Callopora, 347, 348, 351, 357, 359.
Calostylis, 306, 307, 308.
Calycozoa, 206.
Calymene, 519, 533.
Calymenidæ, 532.
Calyptocrinidæ, 429.
Calyptræa, 764.
Calyptræidæ, 764.
Camarella, 671.
Camarophoria, 671.
Camerospongia, 175, 176.
Campanularida, 203.
Campophyllum, 288, 289.
Campylocephalus, 555.
Cancellaria, 798.
Cancellariidæ, 798.
Cancer, 567.
Candona, 507, 509.
Cannapora, 320, 321.
Caprina, 732.
Caprinella, 732.
Caprinula, 732.
Caprotina, 731.
Capulidæ, 764.
Capulus, 764.
Carabidæ, 600.
Carabocrinus, 435.
Carbon and carbonaceous deposits, 34.
Carbonarca, 712.
Carbonicola, 722.
Cardiacea, 726.
Cardiaster, 389.
Cardiidæ, 727.
Cardinia, 721, 722.
Cardiniidæ, 721.
Cardiocaris, 852.
Cardiola, 714.
Cardiomorpha, 750.
Cardita, 723.
Carditidæ, 723.
Cardium, 727, 728.
Caridida, 563.
Carinaria, 802, 803.
Carinopora, 625.
Carmon, 543.
Carpocrinus, 427.
Carterella, 165.
Caryocaris, 514.
Caryocrinus, 455, 456.
Caryocystites, 454.
Caryophyllia, 246, 247, 248, 265, 266.
Cassianella, 704, 705.
Cassidaria, 792.
Cassididæ, 792.
Cassidulidæ, 386, 387.
Cassidulina, 130.

Cassidulus, 388.
Cassis, 792.
Catillocrinidæ, 437.
Catillocrinus, 437.
Catopygus, 388.
Caunopora, 236.
Cavolinia, 806.
Cavoliniidæ, 805.
Cellaria, 635.
Cellariidæ, 634.
Cellepora, 638.
Celleporidæ, 638.
Cellularia, 634.
Cellulariidæ, 634.
Centronella, 674, 675.
Cephalites, 175.
Cephalopoda, 821.
Cerambycidæ, 601.
Ceramopora, 632.
Ceramoporidæ, 632.
Ceratiocaridæ, 512, 513, 514.
Ceratiocaris, 513, 514.
Ceratites, 857.
Ceratitidæ, 856.
Ceratospongiæ, 161.
Ceritella, 789.
Cerithiidæ, 788.
Cerithium, 788.
Chætetes, 341.
Chætetidæ, 327, 341.
Chætognatha, 469.
Chalk, 119.
Chama, 730.
Chamacea, 729.
Chamidæ, 730.
Chasmops, 542.
Cheilostomatous Polyzoa, 633.
Cheirocrinidæ, 437.
Cheirocrinus, 437.
Cheiruridæ, 537.
Cheirurus, 536, 537.
Chelifer, 577.
Chelodes, 818.
Chemnitzia, 784.
Chenendopora, 167.
Chernes, 577.
Chert, 158, 159.
Chilognatha, 585.
Chilopoda, 583.
Chilostomella, 131.
Chilostomellidæ, 122, 130.
Chirodota, 406, 407.
Chiton, 816, 817, 818.
Chitonellus, 818.
Chitonidæ, 816.
Chondrophora, 874, 880.
Chonella, 167.
Chonetes, 657, 658.
Chonostegites, 320, 321.
Choristoceras, 857.
Chrysidalina, 130.
Chrysodomus, 794, 795.
Chrysomelidæ, 600.
Chthamalus, 499.
Cidaridæ, 378.
Cidaris, 378, 379.
Cimitaria, 751.
Cinulia, 801.
Cirripedia, 495.
Cirrus, 772, 773.
Cistella, 676.
Cladiscites, 857.
Cladiscitidæ, 857.
Cladocera, 509.
Cladochonus, 342, 343.
Cladocora, 270.
Cladophyllia, 272.
Classification of the Animal Kingdom, 85, 87.
Classification of Fossiliferous formations, 41.
Clathrodictyon, 233.
Clathropora, 630.
Clausastræa, 304.
Clausilia, 812, 813.
Clavagella, 752.
Clavagellidæ, 751.
Cleidophorus, 716.
Cleiocrinus, 431.
Cleistopora, 306, 310, 311.
Cleodora, 805.
Climacograptus, 218, 220.
Climacospongia, 162.
Climactichnites, 525.
Clinopistha, 748.
Clio, 805, 806, 807.
Cliona, 162.
Clisiophyllidæ, 291.
Clisiophyllum, 292.
Clistenterata, 655.
Clymenia, 852, 853.
Clymeniidæ, 853.
Clypeaster, 385.
Clypeastridæ, 384, 385.
Clypeus, 388.
Cnemidiastrum, 167.
Coccinellidæ, 601.
Coccocrinus, 428.
Coccoliths, 110, 1495.
Coccophyllum, 273.
Cochlearia, 782.
Cochloceras, 857.
Cockroaches, 597.
Codaster, 462, 463, 464.
Codasteridæ, 464.
Codiopsis, 382.
Codonaster, 462.
Codonites, 462.
Cœlenterata, 190.
Cœlocentrus, 772.
Cœloceras, 866, 867.
Cœloptychiidæ, 175.
Cœloptychium, 168, 169, 175.
Cœlospira, 664, 669.
Cœnites, 316.
Cœnobita, 565.
Cœnograptus, 216.
Cœnosphæra, 147.
Coleoprion, 807.
Coleoptera, 600.
Collembola, 592.
Collyrites, 388.

Collyritidæ, 388.
Colonies, 60.
Columbella, 794.
Columbellaria, 794.
Columbellidæ, 793.
Columbellina, 794.
Columnaria, 269, 274.
Columnopora, 306, 317.
Comarocystites, 449, 455.
Comatula, 409, 410, 411, 412, 414, 443.
Comatulidæ, 442.
Combophyllum, 296.
Comoseris, 304.
Conchacea, 735.
Conchicolites, 473, 477, 478.
Conchifera (see *Lamellibranchiata*).
Congeria, 711.
Conidæ, 798.
Conocardium, 728, 729.
Conocephalidæ, 531.
Conocephalites, 531.
Conoclypeidæ, 384.
Conoclypus, 384.
Conocoryphe, 531.
Conodonts, 480.
Conorbis, 799.
Conosmilia, 284.
Contemporaneity of strata, 46.
Continuity, Geological, 55.
Conularia, 808.
Conulariidæ, 808.
Conulus, 812.
Conus, 798, 799.
Convexastræa, 272.
Copepoda, 503, 509.
Coprolites, 15.
Corallines, 25, 1495.
Corallistes, 165.
Corallium, 244, 326, 327, 328.
Coral-reefs, modern and ancient, 256-260.
Coral-rock, 257.
Corals, gemmation and fission of, 253-255.
Corals, simple and compound, 245-255.
Corbicula, 738.
Corbis, 747.
Corbula, 742, 743.
Cornularia, 326.
Cornularidæ, 326, 327.
Cornulites, 475, 476.
Cornuspira, 124.
Coronula, 499.
Corymbocrinus, 430.
Corynella, 180.
Corynida, 195, 197.
Corynoides, 215.
Coscinium, 610, 631, 632.
Coscinopora, 176.
Coscinoporidæ, 176.
Coscinotrypa, 610, 631, 632.
Cosmoceras, 867.
Cottaldia, 382.
Cotylecrinus, 439.
Cotylederma, 439.
Crangopsis, 563.
Crania, 653, 654.
Craniadæ, 653.
Craspedostoma, 776.
Crassatella, 725.
Crassatellidæ, 725.
Crassatellina, 726.
Craticularia, 174.
Crenella, 711.
Crenipecten, 701.
Crepidophyllum, 248, 290.
Crepidula, 764.
Creseis, 804, 805.
Cribrella, 397.
Cribrilina, 636.
Cribrilinidæ, 636.
Crickets, 597.
Crinoidal limestone, 22, 23.
Crinoidea, 408, 1566.
Crioceras, 868, 869, 870.
Crisia, 616.
Crisiidæ, 616.
Cristellaria, 131.
Cromus, 538, 539.
Crossopodia, 486, 487, 1482.
Crotalocrinidæ, 430.
Crotalocrinus, 430, 431.
Crustacea, 491.
Cryphæus, 541, 542.
Cryptoblastus, 464.
Cryptocrinus, 452, 455.
Cryptohelia, 225.
Cryptoplax, 818.
Cryptoschisma, 464.
Cryptozonia, 397.
Crystalline limestones, 31.
Ctenodiscus, 392.
Ctenodonta, 716.
Ctenophora, 256, 260.
Ctenostomata (*Polyzoa*), 612, 613.
Cucullæa, 712, 713.
Cucullella, 715, 717.
Cultellus, 740.
Cumacea, 559, 560.
Cupressocrinidæ, 432.
Cupressocrinus, 433.
Cupularia, 638.
Curculionidæ, 600.
Curculionites, 600.
Curtonotus, 720.
Cuvieria, 806, 810.
Cyathaxonia, 266.
Cyathidium, 439.
Cyathocrinidæ, 435.
Cyathocrinus, 435, 436.
Cyathophyllidæ, 285.
Cyathophylloidea, 284.
Cyathophyllum, 286.
Cybele, 538, 539.
Cyclammina, 129.
Cyclas, 738.
Cycloclypeus, 137.
Cyclocrinus, 186, 187, 188, 1564.
Cyclolites, 305.
Cyclolobus, 855, 856.
Cyclonema, 776.
Cyclophthalmus, 578, 579.
Cyclophyllum, 292.
Cycloseris, 304.

Cyclostoma, 786.
Cyclostomidæ, 786.
Cyclus, 550.
Cylichna, 801, 802.
Cylindrites, 801.
Cylindrophyma, 167.
Cymbulia, 804, 806.
Cymbuliidæ, 806.
Cypellia, 174.
Cyphaspis, 542.
Cyphosoma, 382.
Cypræa, 790, 791.
Cyprædæ, 790.
Cyprella, 508.
Cypricardella, 725.
Cypricardia, 736.
Cypricardinia, 736.
Cypridæ, 508.
Cypridella, 508.
Cypridellina, 508.
Cypridina, 507, 508.
Cypridinidæ, 507.
Cyprina, 736.
Cyprinidæ, 736.
Cypris, 507, 508.
Cyrena, 738.
Cyrenidæ, 738.
Cyrtia, 665, 666.
Cyrtina, 665, 666.
Cyrtoceratidæ, 843.
Cyrtoceras, 843.
Cyrtocerina, 839.
Cyrtodaria, 743.
Cyrtodonta, 714, 715.
Cyrtograptus, 215.
Cyrtolites, 769.
Cystiphyllidæ, 298.
Cystiphylloidea, 298.
Cystiphyllum, 299.
Cystocidaridæ, 373, 374.
Cystocidaris, 373, 374.
Cystodictya, 631.
Cystodictyonidæ, 631.
Cystoidea, 447, 1566.
Cythere, 507, 509.
Cytherea, 737.
Cythereis, 509.
Cytherella, 508.
Cytherellidæ, 508.
Cytherellina, 508.
Cytheridæ, 509.
Cytheridea, 509.

Dakota Beds of North America, 45.
Dalmania, 542.
Dalmanites, 541, 542.
Daonella, 706, 707.
Dasmia, 266.
Davidsonella, 678.
Davidsonia, 663.
Dawsonella, 778.
Dawsonia, 214.
Dayia, 669.
Decapoda (*Crustacea*), 562; (*Cephalopoda*), 874.
Deep-sea Muds, 74.
Defrancia, 619.
Deiphon, 537, 538.
Dekayia, 349, 356.
Delphinula, 775.
Dendrocrinus, 435.
Dendrograptus, 203, 204.
Dendrophyllia, 306, 308.
Dendropupa, 813.
Dentaliidæ, 819.
Dentalina, 131.
Dentalium, 819.
Derivative rocks, 13.
Deshayesia, 779.
Desmoceras, 865.
Diadema, 381.
Diadematidæ, 381.
Dianulites, 356.
Diastoma, 781.
Diastopora, 617, 618.
Diastoporella, 618.
Diastoporidæ, 617.
Diatom-earth, 33, 1490.
Diblasus, 267.
Dibranchiate Cephalopods, 871.
Dibunophyllum, 291, 292.
Dicellograptus, 217.
Diceras, 731.
Dichocrinus, 428.
Dichograptidæ, 216.
Dichograptus, 217, 218.
Dicranograptidæ, 217.
Dicranograptus, 217, 219.
Dictyocha, 147, 148.
Dictyomitra, 148, 149.
Dictyonema, 204, 205.
Dictyoneura, 594.
Dictyonina, 168.
Dictyophyton, 173.
Didymocyrtis, 149.
Didymograptus, 216.
Dikellocephalus, 521, 530, 531.
Dimerella, 670.
Dimorphograptus, 211, 219.
Dimyary Bivalves, 688.
Dindymene, 539.
Dindymenidæ, 539.
Dinobolus, 655.
Dionide, 544.
Diphyphyllum, 287.
Diplocidaris, 379.
Diplodonta, 746, 747.
Diplograptidæ, 218.
Diplograptus, 218, 220.
Diploria, 272.
Diplostylus, 562.
Diplotrypa, 355.
Diprionidian Graptolites, 214, 218.
Diptera, 599.
Discina, 652, 653.
Discinidæ, 652.
Discinisca, 653.
Discites, 846.
Discinocaris, 513, 515.
Discoceras, 844.
Discodermia, 165, 168.
Discohelix, 772.

Discoidea, 386.
Discophora, 206.
Discoporella, 619.
Discorbina, 133.
Discosorus, 840.
Distichopora, 227.
Dithyrocaris, 515.
Ditremaria, 766.
Ditrupa, 475.
Dolabra, 720.
Doliidæ, 792.
Dolium, 792.
Dolomite, 27, 28.
Domopora, 607, 619.
Donacidæ, 739.
Donax, 739.
Dorycrinus, 426.
Doryderma, 165, 167.
Dosinia, 737.
Dragon-flies, 597.
Dreissena, 711.
Dreissenomya, 702, 711.
Dromia, 566.
Dromiopsis, 567.
Duncanella, 264, 267.
Dysaster, 388.
Dysasteridæ, 388.
Dysplanus, 536.
Dytiscidæ, 601.

Earwigs, 597.
Eatonia, 670.
Eburna, 793.
Ecculiomphalus, 771, 772.
Echinanthus, 388, 451.
Echinarachnius, 385.
Echinidæ, 381, 382, 383.
Echinobrissidæ, 387.
Echinobrissus, 388.
Echinocaris, 514.
Echinoconidæ, 385, 386.
Echinoconus, 386.
Echinocoridæ, 389.
Echinocyamus, 385.
Echinocystites, 373, 374.
Echinodermata, 361.
Echinoencrinus, 456.
Echinoidea, 366.
Echinolampadæ, 387.
Echinolampas, 388.
Echinoneus, 387.
Echinonidæ, 387.
Echinospatagus, 390.
Echinosphærites, 454, 455.
Echinothuria, 380.
Echinothuridæ, 380.
Echinozoa, 365.
Echinus, 383.
Edmondia, 750.
Edrioaster, 452, 453.
Edriocrinus, 436, 437.
Eichwaldia, 652.
Elæacrinus, 462, 464.
Elasmostoma, 180, 181.
Elateridæ, 601.
Eleutherocrinus, 462, 464.
Ellipsactinia, 199.
Ellipsocephalus, 529, 531.
Emarginula, 763.
Emmonsia, 314, 315.
Enallocrinus, 431.
Enallohelia, 267.
Enchytræus, 469.
Encrinasteriæ, 395, 396, 397.
Encrinidæ, 438.
Encrinuridæ, 538.
Encrinurus, 538, 539.
Encrinus, 438, 439, 445.
Endoceras, 838.
Endoceratidæ, 837.
Endopachys, 308.
Endophyllum, 286.
Endothyra, 128.
Endymionia, 545.
Enoploclytia, 565.
Ensis, 740.
Entalis, 819.
Entalophora, 618.
Entalophoridæ, 618.
Entolium, 701.
Entomis, 507, 508.
Entomoconchus, 507, 508.
Entomostraca, 503.
Entozoa, 469.
Eocidaris, 378, 379.
Eocystites, 450, 451, 452.
Eoluidia, 397.
Eophrynus, 576.
Eophyton, 209.
Eopteria, 703.
Eoscorpius, 578.
Eosphæroma, 559.
Eospongia, 167.
Eozoön, 137-143.
Epactocrinus, 434.
Ephemeridæ, 597.
Epiaster, 390.
Epitrachys, 469.
Erato, 791.
Eridophyllum, 287.
Erinnys, 543.
Errant Annelides, 478.
Erycina, 726.
Erycinacea, 726.
Erycinidæ, 726.
Eryon, 564, 565.
Eryonidæ, 564.
Eschara, 637.
Escharidæ, 636.
Estheria, 510, 511.
Estheriella, 511.
Etheridgia, 175.
Ethmophyllum, 183, 184, 185.
Etoblattina, 593.
Etyus, 567.
Euasteroidea, 395, 397.
Eubrochus, 176.
Eucalyptocrinus, 429, 430.
Euchrysalis, 787.
Eucladia, 402.
Eucorystes, 567.
Eucyrtidium, 148, 149.

Eudea, 180.
Eudesella, 678.
Eudesicrinus, 439.
Eudiocrinus, 443.
Euechinoidea, 377, 378.
Eugaster, 404, 405.
Eugeniacrinidæ, 439.
Eugeniacrinus, 439.
Eugereon, 594, 595.
Euhelia, 267.
Eulima, 784.
Eumicrotis, 703.
Eunema, 776.
Eunicites, 479, 480.
Euomphalidæ, 770.
Euomphalopterus, 766.
Euomphalus, 770, 771.
Eupatagus, 390.
Euphoberia, 584.
Euphyllia, 262, 272.
Euplectella, 168, 176.
Euproöps, 550.
Eupsammidæ, 306, 307.
Eurete, 174, 176.
Euretidæ, 174.
Euryale, 402.
Euryalida, 402.
Eurydesma, 727.
Eurypterida, 546, 551, 554.
Eurypterus, 551, 552, 555.
Euspongia, 161.
Eustoma, 788.
Exapinurus, 549.
Exelissa, 782.
Exogyra, 696.
Extracrinus, 417, 442.

Farrea, 174, 176.
Fasciculariа, 271, 621.
Fasciculipora, 621.
Fasciolaria, 795.
Favia, 272.
Favistella, 264, 274.
Favosites, 313, 314.
Favositidæ, 306, 311, 312.
Favositipora, 311.
Fenestella, 624, 625.
Fenestellidæ, 608, 622, 623, 624, 625.
Fenestralia, 626.
Fibula, 788.
Ficula, 792.
Ficulidæ, 792.
Filograna, 472.
Firolidæ, 802, 803.
Fission of Corals, 254, 255.
Fissurella, 763.
Fissurellidæ, 763.
Fistularia, 744.
Fistulipora, 357, 358, 359.
Fistuliporidæ, 354, 357.
Flabellum, 246, 266.
Flints, origin of, 158, 159.
Foraminifera, 110.
Forbesiocrinus, 432.
Formicidæ, 600.
Fossil, definition of, 4.
Fossiliferous rocks, 11.
Fossilisation, 5.
Frondicularia, 131.
Frondipora, 621.
Frondiporidæ, 620.
Fulgorina, 595.
Fulgur, 796.
Fungella, 621.
Fungida (*Madreporaria*), 303.
Fungidæ, 304.
Fusidæ, 795.
Fusispira, 787.
Fusulina, 136.
Fusus, 795.

Gadiniidæ, 815.
Gadus, 820.
Galathea, 565, 566.
Galeomma, 726.
Galeommidæ, 726.
Galerites, 386.
Galeropygus, 384.
Gammarus, 557.
Gampsonyx, 557, 561.
Ganymeda, 443.
Gasterocoma, 433, 434.
Gasterocomidæ, 433.
Gasteropoda, 753.
Gastrochæna, 744.
Gastrochænidæ, 744.
Gastropoda, 753.
Gecarcinus, 567.
Gemmation of Corals, 253, 254.
Genabacia, 304.
General succession of organic types, 102.
Geocoma, 403.
Geodia, 163.
Geodites, 163.
Geophilus, 583.
Geoteuthis, 880.
Gephyrea, 469.
Geralinura, 580.
Gervillia, 705.
Gigantostraca, 503, 546.
Gilbertsocrinus, 429.
Girvanella, 127, 128, 1563.
Gitocrangon, 566.
Glandina, 811.
Glauconitic grains of green sands, 34, 118.
Glauconome, 628.
Glenotremites, 443.
Globigerina, 113, 132.
Globigerinidæ, 122, 131, 132.
Glossoceras, 843.
Glycerites, 480.
Glycimeridæ, 743.
Glycimeris, 743.
Glyphæa, 564.
Glyphæidæ, 563, 564.
Glyphostomata, 378, 380.
Glyptarca, 693, 712.
Glypticus, 382.
Glyptocrinidæ, 429.
Glyptocrinus, 428, 429.
Glyptocystites, 456.

Glyptodesma, 708.
Glyptosphærites, 448, 449, 450, 451, 453.
Gnathopod Crustaceans, 503.
Gomphoceras, 840, 841.
Gomphoceratidæ, 841.
Gomphocystites, 452.
Goniaster, 397, 398.
Goniatites, 852, 854.
Goniatitidæ, 853.
Goniodiscus, 397, 398.
Goniomya, 748.
Goniophora, 737.
Goniophorus, 380.
Goniophyllum, 300, 301.
Goniopygus, 382.
Gordiacea, 469.
Gorgonacea, 326.
Gorgonella, 331.
Gorgonia, 330.
Gorgonidæ, 326, 330.
Gosseletia, 708.
Grammysia, 750.
Grammysiidæ, 749.
Granatocrinus, 459, 463, 464.
Grantia, 179.
Graphite, 35.
Graphularia, 331.
Graptolitoidea, 210.
Grasshoppers, 597.
Greensand, 34, 118.
Gromia, 122.
Gromidæ, 122, 124.
Gryllacris, 597.
Gryllus, 597.
Gryphæa, 695, 696.
Gryphochiton, 818.
Gualteria, 390.
Guerangeria, 722.
Guettardia, 176.
Guynia, 266.
Gymnolæmatous Polyzoa, 612.
Gymnosomatous Pteropods, 803, 804.
Gypidula, 672.
Gypsina, 133.
Gypsum, 14.
Gyroceras, 844, 845.
Gyroporella-limestone, 25, 1494.

Hadrophyllidæ, 293, 296.
Hadrophyllum, 296.
Haimeia, 325.
Haimeidæ, 326, 327.
Haliomma, 148, 149.
Haliotidæ, 770.
Haliotis, 770.
Halisarca, 161.
Hallirhoa, 168.
Halobia, 707.
Halycine, 550.
Halysites, 339, 340.
Halysitidæ, 327, 339.
Hamites, 860, 861.
Hamulina, 860.
Haplistion, 163.
Haploceras, 865.
Haploceratidæ, 865.
Haplocrinidæ, 432.
Haplocrinus, 432.
Haplophlebium, 594.
Haplophyllia, 266.
Harpa, 798.
Harpedidæ, 528.
Harpes, 528.
Harpidæ, 798.
Harpides, 543.
Harpoceras, 864, 865.
Harpoceratidæ, 864.
Hartea, 325, 326.
Heart-urchins, 383, 389.
Hederella, 617.
Hedriophthalmate Crustaceans, 556.
Helcion, 762.
Helianthaster, 397.
Heliastræa, 272.
Helicidæ, 811.
Helicina, 778.
Helicinidæ, 778.
Helicoceras, 861.
Helicopora, 626.
Helicotoma, 767.
Heliolites, 335, 336, 337, 338.
Heliolitidæ, 335, 337.
Heliophyllidæ, 289.
Heliophyllum, 289, 290.
Heliopora, 331, 332, 333, 334, 335.
Helioporidæ, 326, 331.
Heliozoa, 109, 110.
Helix, 812.
Helminthochiton, 818.
Hemeristia, 594.
Hemerobiidæ, 598.
Hemiaspidæ, 548.
Hemiaspis, 549.
Hemiaster, 390.
Hemicardium, 728.
Hemiceras, 808.
Hemicidaris, 381, 382.
Hemicosmites, 447, 455.
Hemicystites, 452.
Hemimetabolic Insects, 592.
Hemipedina, 382.
Hemipronites, 661.
Hemiptera, 595.
Hemitrochiscus, 566.
Hercoceras, 845.
Hermit-crabs, 565.
Heteractinellidæ, 160, 178.
Heterastridium, 227.
Heteroblastus, 464.
Heteroceras, 861, 869.
Heterocœla, 179.
Heterocrinidæ, 434.
Heterocrinus, 434.
Heterodictya, 628, 629.
Heterophyllia, 265, 269, 271.
Heteropoda, 802.
Heteropora, 611, 612, 615, 621, 622.
Heteroporella, 621, 622.
Heteroporidæ, 621.
Heteropsammia, 317.
Heterostegina, 137.
Hexacrinidæ, 428.

Hexacrinus, 428.
Hexactinellidæ, 168.
Hexarhizites, 208.
Hildoceras, 865.
Hindia, 165, 167.
Hinnites, 701.
Hipponyx, 764.
Hippopodium, 724.
Hippopus, 727.
Hippothoa, 613, 636.
Hippothoidæ, 636.
Hippurites, 733, 734.
Hippuritidæ, 732.
Hirudinea, 470.
Histioderma, 481, 482.
Hoërnesia, 705.
Holaster, 243, 389.
Holasterella, 173.
Holasteridæ, 389.
Holectypus, 386.
Holochiton, 818.
Holocystis, 272, 273.
Holocystites, 454, 455.
Holometabolic Insects, 599.
Holopea, 781.
Holopella, 782.
Holopidæ, 439.
Holopus, 439.
Holostomatous Gastropods, 755, 761.
Holothuroidea, 406.
Homalonotus, 533.
Homarus, 565.
Homocœla, 178.
Homocrinus, 436.
Homotaxeous deposits, 46.
Homothetus, 594.
Hoplites, 867.
Hoplocrinus, 434.
Hoploparia, 565.
Hornera, 618.
Horny Sponges, 161.
Huronia, 840.
Hyalæa, 803, 806.
Hyalocylix, 805.
Hyalonema, 170.
Hyalostelia, 170.
Hyalotragos, 167.
Hyboclypus, 387.
Hybocrinidæ, 434.
Hybocrinus, 434.
Hybocystites, 434.
Hydra, 193.
Hydractinia, 197, 198, 199.
Hydrida, 190.
Hydrobia, 780, 781.
Hydrocephalus, 530.
Hydrocorallinæ, 191, 223.
Hydroid Zoophytes, 195.
Hydrophilidæ, 601.
Hydrozoa, 192.
Hymenocaris, 513, 514.
Hymenoptera, 599.
Hyocrinidæ, 439.
Hyocrinus, 440.
Hyolithes, 804, 807.
Hyolithidæ, 807.
Hypanthocrinus, 430.
Hyperammina, 127.
Hypotrema, 698.
Hystricrinus, 418, 428.

Ianthina, 782.
Ianthinidæ, 782.
Ichthyocrinidæ, 431, 445, 446.
Ichthyocrinus, 431.
Ichthyosarcolites, 732.
Idiostroma, 236.
Idmonea, 618.
Idmoneidæ, 618.
Illænidæ, 535.
Illænus, 535, 536.
Imperator, 775.
Imperfection of the palæontological record, 63.
Imperforate Foraminifera, 120, 121, 122.
Indusial Limestone, 598.
Infusoria, 110.
Inkbag of Cuttlefishes, 822, 871.
Inoceramus, 705, 706.
Insecta, 587.
Involutina, 129.
Irregular Echinoids, 383.
Isastræa, 271, 272.
Ischadites, 170, 172, 173, 1564.
Isis, 330.
Isoarca, 712.
Isocardia, 736.
Isochilina, 506, 507.
Isodonta, 739.
Isonema, 776.
Isopoda, 556, 558.
Isotelus, 534.
Iulopsis, 585.

Jelly-fishes, 206.
Jerea, 167, 168.
Jereica, 167.

Kampecaris, 584.
Keilostoma, 781.
Kellia, 726.
Kingena, 675.
King-crabs, 546, 550.
Kirkbya, 506.
Klitambonites, 661.
Koninckella, 663, 664.
Koninckia, 311.
Koninckina, 664.
Koninckinidæ, 663.
Kraussina, 675.
Kröyera, burrows of, 488.
Kutorgina, 651.

Labechia, 232, 233.
Lace-corals, 622.
Laceripora, 315.
Lacuna, 781.
Læmodipoda, 558.
Lævicardium, 728.
Lagena, 131.
Lagenidæ, 122, 131.
Lakhmina, 651, 652.

Lamellibranchiata, 683.
Laramie group of North America, 46.
Lasiocladia, 163.
Lasiograptidæ, 219.
Lasiograptus, 219.
Latimæandra, 272.
Leaia, 511.
Lecanocrinus, 431.
Leda, 717.
Legnodesmus, 481.
Leiopathes, 263.
Leiopteria, 703.
Leiorhynchus, 670.
Leitha-kalk, 25, 1497.
Lepadidæ, 500.
Lepadocrinus, 449, 456.
Lepas, 500, 502.
Leperditia, 506, 507.
Leperditidæ, 506.
Lepidechinus, 377.
Lepidesthes, 376.
Lepidocentrus, 377.
Lepidoptera, 599.
Lepisma, 592.
Lepralia, 636, 637.
Leptæna, 659, 663.
Leptagonia, 662.
Leptobolus, 652.
Leptochiton, 818.
Leptoclinum, 603.
Leptocœlia, 675.
Leptodomus, 750.
Leptograptidæ, 216.
Leptograptus, 216.
Leptomaria, 766.
Lepton, 726.
Leptophyllia, 305.
Leptoteuthis, 880, 881.
Leucandra, 179, 1565.
Leucones, 179, 1565.
Leuconia, 179.
Leuconidæ, 179.
Leucosolenia, 179.
Libellulidæ, 597.
Lichadæ, 540.
Lichas, 539, 540.
Lichenopora, 612, 619.
Lichenoporidæ, 619.
Life-zones, 58.
Lima, 700.
Limacidæ, 811.
Limacina, 804.
Limacinidæ, 804.
Limanomia, 698.
Limea, 700.
Limestones, origin and microscopic structure of, 15-32.
Limidæ, 699.
Limnadia, 510.
Limnæa, 814.
Limnæidæ, 813.
Limopsis, 713, 714.
Limoptera, 703.
Limulidæ, 550.
Limulus, 546, 547, 548, 551.
Lindstræmia, 266.
Lingula, 650.
Lingulella, 650, 651.
Lingulepis, 650.
Lingulidæ, 650.
Linthia, 390.
Liopistha, 749.
Litharæa, 311.
Lithentomum, 594.
Lithistidæ, 164.
Lithocardium, 728.
Lithodomus, 711.
Lithogaster, 563.
Lithographic Limestones, 18.
Lithomantis, 594.
Lithostrotion, 287, 288.
Littorina, 781.
Littorinidæ, 781.
Lituites, 844.
Lituitidæ, 844.
Lituola, 128.
Lituolidæ, 122, 128.
Lobites, 856.
Lobocarcinus, 567.
Locusta, 597.
Loftusia, 129, 130.
Lonsdaleia, 292, 293.
Lophohelia, 262, 267, 268.
Lophophyllum, 295.
Lophoseridæ, 304.
Lophoseris, 304.
Loricula, 500, 502.
Loxonema, 784.
Lucernaria, 195, 206.
Lucernarida, 206.
Lucina, 746, 747.
Lucinacea, 746.
Lucinidæ, 746.
Luidia, 392, 393.
Lumbricaria, 484.
Lumbriconereites, 479, 480.
Lunatia, 779.
Lunulicardiidæ, 729.
Lunulicardium, 729.
Lunulites, 638.
Lutraria, 742.
Lychnocanium, 149.
Lymnocardium, 728.
Lymnorea, 180.
Lyonsia, 749.
Lyopomata, 649.
Lyra, 675.
Lyrodesma, 713, 717.
Lyropora, 626.
Lyssakina, 168.
Lytoceras, 859, 860.
Lytoceratidæ, 859.
Lyttonia, 678.

Maclurea, 772, 773.
Macrocheilus, 784, 785.
Macrodon, 713.
Macropneustes, 390.
Macroscaphites, 860.
Macrura, 562.
Mactra, 741, 742.
Mactridæ, 741.

Madrepora, 308, 309.
Madreporaria, 263, 264.
Madreporidæ, 308.
Mæandrina, 272.
Mæandropora, 621.
Mæandrospongidæ, 175.
Magas, 675.
Magnesian limestone, 27.
Malacodermata (*Zoantharia*), 263.
Malacostraca, 556.
Malleus, 704.
Mallophaga, 592.
Malocystites, 452.
Mandibles of Cephalopods, 822, 827, 828, 871.
Mantidæ, 597.
Marginella, 797.
Marginulina, 131.
Marsupites, 442.
Marsupitidæ, 442.
Martesia, 745.
Mastopora, 188, 1564.
Mastosia, 167.
Matheria, 724.
Mazonia, 578.
Mecochirus, 564.
Medusites, 208.
Megalaspis, 534, 535.
Megalodon, 735, 736.
Megalodontidæ, 735.
Megalomus, 714, 716.
Megamorina, 164.
Meganteris, 675.
Megaphyllites, 859.
Megerlia, 675.
Megistocrinus, 426.
Melania, 785.
Melaniidæ, 785.
Melanopsis, 785.
Melina, 704.
Melithæa, 327.
Mellitionidæ, 176.
Melocrinidæ, 426, 429.
Melocrinus, 426.
Melonella, 167.
Melongena, 796.
Melonites, 376.
Membranipora, 635.
Membraniporidæ, 635.
Menocephalus, 531.
Menophyllum, 295.
Meretrix, 737.
Meringosoma, 479.
Merista, 666, 667.
Meristella, 666, 667.
Mermis, 469.
Merostomata, 546.
Merulina, 272.
Mesenteripora, 617, 618.
Mesoblastus, 463.
Mespilocrinus, 431.
Metablastus, 463.
Metacrinus, 442.
Metoptoma, 762, 763.
Meyeria, 565.
Miamia, 594.
Michelinia, 316, 317.
Micrabacia, 304.
Micraster, 389, 390.
Microconchus, 474.
Microcyclus, 296.
Microdiscus, 545.
Microdon, 725.
Micropora, 635, 636.
Microporella, 636.
Microporellidæ, 636.
Microporidæ, 635.
Microsolena, 305.
Migrations, 50.
Miliola, 124.
Miliolidæ, 122, 124.
Millepora, 223, 224.
Millericrinus, 440.
Mitcheldeania, 200, 201.
Mitra, 797.
Modiola, 710.
Modiolopsidæ, 718.
Modiolopsis, 718.
Modiomorpha, 718.
Mollusca, 680.
Molluscoidea, 603.
Monactinellidæ, 161.
Monera, 109, 110.
Monilopora, 342.
Monodonta, 775.
Monograptidæ, 215.
Monograptus, 215.
Monomerella, 654, 655.
Monomyary Bivalves, 689, 692.
Monopleura, 731.
Monoprionidian Graptolites, 214.
Monopteria, 703.
Monotis, 706.
Monotrypa, 347, 356.
Monotrypella, 356.
Monoxenia, 325, 326.
Montacuta, 726.
Monticulipora, 347, 351, 354, 355.
Monticuliporidæ, 346, 354.
Monticuliporoids, 346.
Montlivaltia, 270.
Moorea, 506.
Mopsea, 327, 328.
Moseleya, 274.
Mucronella, 637.
Murchisonia, 767, 768.
Murex, 796.
Muricidæ, 796.
Mussa, 262, 264, 272.
Mya, 742.
Myacea, 741.
Myalina, 708, 709.
Mycedium, 304.
Myidæ, 742.
Mylacris, 593.
Mylothrites, 599.
Myocaris, 511.
Myoconcha, 724.
Myophoria, 720.
Myrianites, 485, 486.
Myriopoda, 580.
Myriozoidæ, 636.

Myrmeleontidæ, 598.
Mysis, 560, 561.
Mystrophora, 661.
Mytilacea, 702.
Mytilarca, 708.
Mytilidæ, 710.
Mytilus, 710.
Myxospongiæ, 161.
Myzostoma, 469.
Myzostomida, 469.

Nanocrinus, 433, 434.
Narica, 779.
Nassa, 793.
Nassellaria, 145, 146.
Natica, 779.
Naticella, 779.
Naticidæ, 778.
Naticopsis, 778.
Nautilidæ, 844.
Nautiloidea, 833, 834.
Nautilus, 826, 827, 845, 846.
Neæra, 743.
Nebalia, 510, 512.
Nebaliadæ, 512, 513.
Nebaliopsis, 512.
Necrocarcinus, 567.
Necrogammarus, 557.
Necroscilla, 562.
Nectotelson, 561.
Nematoda, 469.
Nemerteans, 480.
Nemertites, 480.
Neobolus, 651, 652.
Neocrinoidea, 423, 424, 438, 445.
Neolimulus, 549, 550.
Neorinopsis, 599.
Neoscorpii, 579.
Nereidavus, 480.
Nereites, 480, 484, 485.
Nerinea, 787, 788.
Nerineidæ, 787.
Nerita, 777.
Neritidæ, 776.
Neritina, 777.
Neritodomus, 777.
Neritoma, 777.
Neritopsidæ, 777.
Neritopsis, 777.
Neuroptera, 597.
Nidulites, 187, 188, 1564.
Nileus, 535.
Niobe, 534.
Niso, 784.
Nodosaria, 131.
Nodosinella, 129.
Nonionina, 134.
Nothoceras, 847.
Nubecularia, 124.
Nucleoblastidæ, 463.
Nucleobranchiata, 802.
Nucleospira, 667.
Nucula, 715, 716.
Nuculana, 717.
Nuculanidæ, 717.
Nuculidæ, 714.
Nuculina, 714.
Nudibranchiate Gastropods, 756, 758, 800.
Nulliporen-kalk, 25.
Nullipores, 24, 25, 1496.
Nummulina, 134, 135.
Nummulinidæ, 123, 133.
Nummulitic limestone, 120, 136.

Obolella, 651.
Obolidæ, 650.
Obolus, 651.
Oceanic Hydrozoa, 195.
Octactinellidæ, 177.
Octillænus, 536.
Octopod Cephalopods, 873, 881.
Oculina, 267.
Oculinidæ, 267.
Oculospongia, 180.
Odontomaria, 766.
Odostomia, 784.
Ogygia, 534.
Oldhamia, 205.
Oldhamina, 678.
Olenellus, 529.
Olenidæ, 528.
Olenus, 530, 531.
Oligochæta, 470.
Oligoporus, 376.
Oliva, 798.
Olivella, 798.
Olividæ, 798.
Ollacrinus, 429.
Omphyma, 282, 288.
Oniscia, 792.
Oniscidæ, 559.
Oniscus, 559.
Onychaster, 402.
Onychophora, 582.
Oolitic structure of limestones, 28.
Operculina, 137.
Ophidioceras, 844.
Ophileta, 771.
Ophioderma, 403.
Ophioglypha, 400, 403.
Ophiolepis, 404.
Ophiurella, 403.
Ophiurida, 403.
Ophiuroidea, 399.
Opis, 725.
Opisthobranchiate Gastropods, 800.
Oppelia, 865.
Orbicular silica, 7.
Orbiculoidea, 653.
Orbitoides, 137.
Orbitolites, 125, 126.
Orbulina, 132.
Orchestia, 557.
Oreaster, 398.
Organic types, succession of, 96.
Oriostoma, 775.
Orophocrinus, 462, 463, 464.
Orozoë, 514.
Orthis, 658, 659, 660.
Orthisina, 661.
Orthoceras, 836, 837.

Orthoceratidæ, 836.
Orthodesma, 741.
Orthonema, 785.
Orthonota, 741.
Orthonychia, 765.
Orthoptera, 597.
Orthotetes, 663.
Ortonia, 476, 477.
Ostracoda, 503, 504, 505.
Ostrea, 695.
Ostreacea, 694.
Ostreidæ, 694, 695.
Ovarian capsules of Graptolites, 213, 214.
Ovulum, 791.
Oxynoticeras, 864.

Pachastrella, 163, 164.
Pachydomus, 725.
Pachypora, 314, 315.
Pachypoterion, 165.
Pachypteria, 695, 699.
Pachyrisma, 736.
Pachyteichisma, 174.
Pagurus, 565, 566.
Palæacis, 306, 307, 309, 310.
Palæacmæa, 762.
Palæanatina, 750, 751.
Palæarca, 714.
Palæaster, 395, 396.
Palæchinus, 373, 375.
Palæga, 559.
Palægina, 206.
Palæinachus, 567.
Palæoblattina, 591, 593.
Palæocampa, 582, 583.
Palæocaris, 557, 561.
Palæocarpilius, 567.
Palæochorda, 483, 1482.
Palæocoma, 396, 397.
Palæocoryne, 202.
Palæocorystes, 567.
Palæocrangon, 557.
Palæocreusia, 499.
Palæocrinoidea, 423, 424, 425, 445.
Palæocyclidæ, 296.
Palæocyclus, 280, 281, 296, 297.
Palæocypris, 509.
Palæocystites, 455.
Palæodictyoptera, 592, 593.
Palæodiscus, 397.
Palæomanon, 167.
Palæomyrmex, 600.
Palæoneilo, 717.
Palæontina, 596.
Palæontological Record, imperfection of, 63.
Palæontological zones, 58.
Palæontology, relations and methods of, 82.
Palæopalæmon, 563.
Palæophonus, 578.
Palæophycus, 483.
Palæopinna, 709.
Palæopyge, 527.
Palæorchestia, 557, 561.
Palæosolen, 741.
Palasterina, 396, 397.
Palastropecten, 398.
Palechinoidea, 372, 373.
Paleschara, 613.
Palinuridæ, 564.
Palinurus, 565.
Paludina, 780.
Paludinidæ, 780.
Panderia, 536.
Pandora, 749.
Panopæa, 743.
Panorpidæ, 598.
Paolia, 594.
Paper Nautilus, 881.
Papyridea, 728.
Parabolina, 531.
Paradoxidæ, 528.
Paradoxides, 529, 530.
Parallelodon, 713.
Paramuricea, 300.
Paranebalia, 512.
Parapholas, 745.
Parasmilia, 270.
Parka, 554.
Parkeria, 199, 200.
Pasceolus, 186, 187.
Patella, 762.
Patellidæ, 762.
Pauropus, 581, 582.
Pavonaria, 331.
Pearly Nautilus, 826, 827, 828.
Pecten, 701.
Pectinacea, 698.
Pectinaria, 471.
Pectinated rhombs of Cystideans, 450, 451.
Pectinidæ, 700.
Pectunculus, 713.
Pedinopsis, 383.
Pedipalpi, 577.
Pedunculated Cirripedes, 500.
Pelmatozoa, 364, 408.
Peltarion, 778.
Peltastes, 379.
Peltocaris, 513, 515.
Peltoceras, 868.
Peltura, 531.
Pemphix, 563.
Pen of Cuttle-fishes, 872, 880.
Penæus, 563, 564.
Peneroplis, 124.
Pennatulacea, 327.
Pennatulidæ, 327, 331.
Pentaceros, 393, 397, 398.
Pentacrinidæ, 441.
Pentacrinus, 415, 441.
Pentamerella, 672.
Pentamerus, 671, 672.
Pentatremites, 462.
Pentephyllum, 464.
Pentremites, 458, 459, 460, 461, 462, 463.
Pentremitidæ, 463.
Pentremitidea, 463.
Perforate Corals, 306.
Perforate Foraminifera, 121, 122, 130.
Periaster, 390.

Peridinium, 110.
Periechocrinus, 426.
Peripatus, 581, 582.
Perischodomus, 377.
Perischoechinidæ, 373, 375.
Perisphinctes, 867.
Perlidæ, 597.
Perna, 704.
Pernopecten, 701.
Pernostrea, 697.
Peronella, 179.
Petraia, 265, 267.
Petraster, 396.
Petricola, 738.
Phacopidæ, 541.
Phacops, 541.
Phædra, 557.
Phænoschisma, 462, 464.
Phæodaria, 145, 146, 147.
Phalangidæ, 577.
Phalaranea, 580.
Phanerozonia, 397, 398.
Pharetrones, 178, 179, 180, 181.
Pharetronidæ, 179.
Pharetrospongia, 181.
Phasianella, 775, 776.
Phasmidæ, 597.
Phillipsastræa, 284, 290.
Phillipsia, 528, 543.
Pholadidæ, 744.
Pholadidea, 744, 745.
Pholadomya, 751.
Pholadomyidæ, 751.
Pholas, 745.
Pholidophyllum, 283, 296.
Phormosoma, 380.
Phorus, 776, 777.
Phosphate of lime, 15.
Phragmoceras, 840, 841.
Phragmophora, 874.
Phryganeidæ, 598.
Phrynidea, 579.
Phrynus, 580.
Phthanocoris, 595.
Phylactolæmatous Polyzoa, 612.
Phyllocarida, 512.
Phylloceras, 858, 859.
Phylloceratidæ, 858.
Phyllodocites, 484, 485.
Phyllograptidæ, 220, 221.
Phyllograptus, 220, 221.
Phyllopoda, 510.
Phyllopora, 626.
Phyllosoma, 564.
Phylloteuthis, 880.
Phymechinus, 383.
Physa, 814.
Physophoridæ, 195.
Pikermi beds, 46.
Pileolus, 777.
Pileopsis, 764.
Piloceras, 838, 839.
Pinacoceras, 858.
Pinacoceratidæ, 857.
Pinacopora, 338.
Pinna, 709.
Pinnatopora, 627, 628.
Pinnidæ, 709.
Pirena, 785.
Pisania, 795.
Pisidium, 738.
Pisocrinus, 432.
Placonella, 167.
Placoparia, 537.
Placotrochus, 266.
Placuna, 697, 698.
Placunopsis, 698.
Plagioptychus, 732.
Plagiostoma, 700.
Planolites, 483.
Planorbis, 814.
Planorbulina, 133.
Plasmopora, 338.
Platephemera, 594.
Platyceras, 764, 765.
Platychonia, 167.
Platycrinidæ, 427.
Platycrinus, 427, 428.
Platyschisma, 771.
Platystoma, 765.
Platystrophia, 659, 660.
Plectambonites, 662.
Plectoderma, 173.
Plesiastræa, 272.
Plesiofungidæ, 303.
Plesioporitidæ, 305.
Plesioteuthis, 880, 881.
Plethospongiæ, 160, 161.
Pleurobranchidæ, 802.
Pleurocera, 785.
Pleurocystites, 449, 451, 456.
Pleurodictyum, 316, 317.
Pleurograptus, 216.
Pleuromya, 748.
Pleuronotus, 773, 774.
Pleurope, 176.
Pleurophorus, 723, 724.
Pleuropygia, 649.
Pleurotoma, 799.
Pleurotomaria, 765, 766, 767.
Pleurotomariidæ, 765.
Pleurotomidæ, 799.
Plicatocrinidæ, 440.
Plicatocrinus, 440.
Plicatula, 699.
Plinthosella, 167.
Plocoscyphia, 175.
Plumaster, 399.
Plumulites, 501, 502.
Plutonia, 529.
Pocillopora, 244, 269.
Pocilloporidæ, 268.
Podocyrtis, 148, 149.
Podophthalmate Crustaceans, 556, 559.
Podoseris, 304.
Podura, 592.
Pœcilasma, 496, 502.
Pœcilopoda, 546.
Polir-schiefer, 33, 1490.
Pollicipes, 502.
Polychætous Annelides, 470, 471.
Polycælia, 265, 267.

Polycope, 507, 508.
Polycopidæ, 508.
Polycyphus, 383.
Polycystina, 145, 146, 147.
Polyplacophora, 816.
Polymorphina, 131.
Polyphemopsis, 787.
Polypora, 624.
Polystomella, 134.
Polytrema, 133.
Polytremacis, 335.
Polytremaria, 766.
Polyzoa, 604.
Pontocypris, 509.
Porambonites, 672.
Porcellia, 767.
Porcellio, 559.
Porella, 637.
Porites, 310.
Poritidæ, 306, 309, 310.
Porocidaris, 379.
Porosphæra, 200.
Posidonia, 707.
Posidoniella, 706.
Posidonomya, 707.
Potamides, 788.
Poterioceras, 843.
Poterioceratidæ, 843.
Poteriocrinidæ, 435, 436.
Poteriocrinus, 418, 436.
Præarcturus, 559.
Præcardiidæ, 751.
Præcardium, 751.
Prasina, 702.
Prasopora, 351.
Prestwichia, 550.
Primitia, 506, 507.
Primnoa, 300, 331.
Prionastræa, 272.
Proboscina, 616.
Producta, 655, 656, 657.
Productella, 657.
Productidæ, 655.
Proetidæ, 542.
Proetus, 542.
Progonoblattina, 593.
Propora, 338.
Proscorpius, 578.
Prosobranchiate Gastropods, 760.
Prosopon, 567.
Prosoponiscus, 557.
Protachilleum, 167.
Protaræa, 306, 309, 311.
Protaster, 404, 405.
Protichnites, 524, 525.
Protobalanus, 499.
Protocaris, 514.
Protocystites, 451.
Protolimulus, 550.
Protolycosa, 575, 580.
Protopharetra, 184, 185.
Protophasma, 594.
Protophiurida, 404.
Protoseris, 304.
Protospongia, 157, 169.
Protosycon, 179.
Protosyngnatha, 582.
Protozoa, 109.
Psammobia, 739.
Psammobiidæ, 739.
Psammocarcinus, 576.
Pseudastacus, 564.
Pseudaxonia, 326, 327.
Pseudedmondia, 739.
Pseudocrania, 654.
Pseudocrinus, 456.
Pseudodiadema, 381, 382.
Pseudofungidæ, 273.
Pseudomelania, 785.
Pseudomelaniidæ, 784.
Pseudomonotis, 703, 704.
Pseudoneuroptera, 597.
Pseudoniscus, 549.
Pseudoscorpionidæ, 577.
Pseudoturbinolidæ, 266.
Psilocephalus, 535.
Psolus, 406, 407.
Pterinea, 707.
Pterocaris, 515.
Pteroceras, 789, 790.
Pteronites, 703.
Pteropoda, 803.
Pteropodal limestone, 24, 805.
Pterostoma, 781.
Pterotheca, 807.
Pterygometopus, 541, 542.
Pterygotus, 552, 553, 554, 555.
Ptilodictya, 628, 629, 630.
Ptilodictyonidæ, 628.
Ptilograptus, 204, 205.
Ptilonaster, 404, 405.
Ptilopora, 626.
Ptychites, 862.
Ptychitidæ, 861.
Ptychoceras, 860, 861.
Ptychophyllum, 298.
Pugiunculus, 807.
Pulmonate Gastropods, 810.
Pulvinulina, 133.
Pupa, 813.
Purpura, 794.
Purpuridæ, 794.
Purpuroidea, 794.
Pustulopora, 618.
Pygaster, 384, 386.
Pygaulus, 388.
Pycnogonida, 575.
Pygocephalus, 563.
Pygurus, 388.
Pyramidella, 784.
Pyramidellidæ, 783.
Pyrgia, 342, 343.
Pyrgoma, 499.
Pyrina, 387.
Pyrula, 792, 796.

Quenstedtia, 740.
Quinqueloculina, 124.

Radiata, 190.
Radiolaria, 144.
Radiolarian coprolites, 148.

Radiolarian ooze, 146.
Radiolarian quartzites, 147.
Radiolites, 734.
Radiopora, 619.
Ranella, 793.
Rapana, 794, 795.
Rastrites, 215, 216.
Receptaculites, 170, 171, 172, 173.
Receptaculitidæ, 170, 1563.
Red Coral, 327.
Redonia, 716.
Reef-building Corals, 256, 257.
Regular Echinoids, 378.
Remopleuridæ, 528.
Remopleurides, 528.
Reniera, 163.
Rensselæria, 675.
Reptaria, 617.
Requienia, 730, 731.
Retepora, 609, 610, 626, 637, 638.
Reteporidæ, 637.
Retiolites, 220, 221.
Retiolitidæ, 219.
Retzia, 666, 667.
Rhabdoceras, 857.
Rhabdocidaris, 379.
Rhabdomeson, 632, 633.
Rhabdomesontidæ, 632.
Rhabdophora, 210.
Rhabdopleura, 222.
Rhaphistoma, 767.
Rhipidogyra, 272.
Rhizangia, 270.
Rhizocephala, 497.
Rhizocrinus, 441.
Rhizomorina, 164.
Rhizophyllum, 299, 301.
Rhizopoda, 109.
Rhizopoterion, 175.
Rhizostomidæ, 206.
Rhizostomites, 207.
Rhodarœa, 311.
Rhodocrinidæ, 428.
Rhodocrinus, 419, 428.
Rhoëchinus, 377.
Rhombina, 508.
Rhombopora, 610.
Rhopalastrum, 149.
Rhyncholites, 828.
Rhynchonella, 669, 670.
Rhynchonellidæ, 669.
Rhynchoporina, 670.
Rhynchospira, 668.
Rhynchota, 595.
Rhynchoteuthis, 828.
Ribeiria, 511.
Richmond earth, 34, 1490.
Rimula, 763.
Ringicula, 801.
Rissoa, 780, 781.
Rissoidæ, 780.
Rissoina, 781.
Robulina, 131.
Rocks, classification of, 9.
Roemeria, 319.
Romingeria, 319.
Rosenella, 233.
Rostellaria, 790, 791.
Rotalia, 133.
Rotalidæ, 132.
Rudistæ, 732.
Rugosa, 256, 262, 264, 276.
Rusichnites, 525.
Rusophycus, 525.
Rutotia, 706.

Sabella, 471.
Sabellaria, 471.
Saccammina, 126.
Saccocoma, 444, 445.
Saccocomidæ, 444.
Sactoceras, 840.
Sageceras, 858.
Salenia, 379.
Salenidæ, 379.
Salicornaria, 635.
Salicornariadæ, 634.
Salmacis, 383.
Salpingostoma, 769.
Salterella, 808.
Sanguinolites, 750.
Sao, 529, 531.
Saxicava, 743, 744.
Scalaria, 781, 782.
Scalariidæ, 781.
Scalites, 767.
Scalpellum, 502.
Scaphander, 802.
Scaphiocrinus, 436.
Scaphites, 868.
Scaphopoda, 819.
Scarabœidæ, 601.
Schizaster, 390.
Schizoblastus, 463, 464.
Schizocrania, 654.
Schizodiscus, 511.
Schizodus, 720.
Schizopholis, 651, 652.
Schizopoda, 560, 561.
Schizoporella, 636, 637.
Schizostoma, 771.
Schloenbachia, 863.
Schmidtia, 650.
Scintilla, 726.
Scissurella, 775.
Sclerogorgia, 328.
Scolecida, 469.
Scolecoderma, 475.
Scoliostoma, 782.
Scolithus, 481.
Scorpiodea, 577.
Scorpion, 573, 574, 577.
Scorpion-flies, 598.
Scrobicularia, 748.
Scrobiculariidæ, 747.
Scrupocellaria, 634.
Sculda, 562.
Scutella, 369, 385.
Scyllarus, 565.
Sea-anemones, 241.
Sea-cucumbers, 406.
Sea-urchins, 366.

Sedimentary rocks, origin of, 11.
Selenaria, 638.
Selenariidæ, 638.
Seliscothon, 164, 166.
Semele, 748.
Semicoscinium, 625.
Sepia, 879, 880.
Sepiophora, 874, 879.
Septastræa, 246, 272.
Septifer, 711.
Septopora, 628.
Seraphs, 790.
Seriatopora, 262, 268, 269.
Serpula, 471, 472, 473.
Serpulites, 475.
Sertularida, 203.
Sessile Cirripedes, 497, 499.
Sestrostomella, 180.
Shumardia, 545.
Sialidæ, 598.
Sigaretus, 779.
Siliceous organic deposits, 32.
Silicification, 7.
Silicispongiæ, 160.
Siliqua, 740.
Siliquaria, 783.
Simoceras, 868.
Siphonaria, 815.
Siphonariidæ, 815.
Siphonate Bivalves, 691, 692.
Siphonia, 167, 168.
Siphonodentalium, 820.
Siphonostomatous Gastropods, 760, 761.
Siphonotreta, 652.
Skenidium, 660, 661.
Slimonia, 555.
Smilotrochus, 266.
Smithia, 290.
Smittia, 637.
Smynthurus, 592.
Solanocrinus, 443.
Solariidæ, 774.
Solarium, 774.
Solaster, 393, 397, 399.
Solecurtus, 740.
Solemya, 748.
Solemyidæ, 748.
Solen, 740.
Solenidæ, 740.
Soleniscus, 785.
Solenopora, 200, 201.
Solenopsis, 741.
Sowerbya, 739.
Spatangidæ, 389.
Spatangus, 390.
Spathiocaris, 852.
Sphæractinia, 199.
Sphærechinus, 383.
Sphærexochus, 537.
Sphærium, 738.
Sphæronites, 454.
Sphærospongia, 173, 1564.
Sphærulites, 734.
Sphenaulax, 174.
Sphenotrochus, 266.
Sphinx, 599.
Spirialis, 805.
Spirifera, 664, 665
Spiriferidæ, 664.
Spiriferina, 665.
Spirigera, 666.
Spirillina, 133.
Spirocyathus, 184.
Spiropora, 618.
Spirorbis, 472, 473.
Spirula, 873, 875.
Spirulidæ, 875.
Spirulirostra, 878.
Spondylidæ, 698.
Spondylus, 698, 699.
Spongilla, 158.
Spongillidæ, 155.
Spongillopsis, 163.
Spongites, 161.
Spongophyllum, 286.
Sporadopora, 225, 229.
Sporadopyle, 174.
Spumellaria, 145, 147.
Squilla, 562.
Stacheia, 129.
Staphylinidæ, 601.
Stauractinella, 168, 174.
Stauria, 264, 273.
Stauridæ, 273.
Staurocephalus, 537.
Stauroderma, 174.
Staurodermidæ, 174, 176.
Stauronema, 176.
Stelidiocrinus, 427.
Stellaster, 398.
Stellispongia, 180.
Stenaster, 396.
Stenocrinus, 434.
Stenopora, 350.
Stenoschisma, 671.
Stephanastrum, 149.
Stephanoceras, 866.
Stephanoceratidæ, 865.
Stephanophyllia, 308.
Stereoplasma, 245.
Stictopora, 630.
Stictoporidæ, 630.
Stoliczkaria, 227, 228, 229.
Stomatia, 770.
Stomatiidæ, 770.
Stomatopoda, 561.
Stomatopora, 616, 617.
Stomatoporidæ, 616.
Stomechinus, 383.
Stone-flies, 597.
Straparollus, 770, 771.
Strata, contemporaneity of, 46.
Streblopteria, 702.
Strephochetus, 127.
Strepsiptera, 600.
Streptelasma, 278, 279, 280.
Streptorhynchus, 663.
Striatopora, 315.
Stricklandia, 672.
Stricklandinia, 672.
Stringocephalidæ, 676.
Stringocephalus, 676, 677.

Strobilepis, 501.
Strobilocystites, 452.
Stromatactis, 21.
Stromatopora, 235, 236, 237.
Stromatoporella, 236, 237.
Stromatoporoidea, 229, 1564.
Strombidæ, 789.
Strombodes, 287.
Strombus, 789.
Strongylocentrotus, 383.
Strophalosia, 657.
Strophomena, 659, 660, 661, 662.
Strophomenidæ, 658.
Strophostylus, 765.
Stygina, 535.
Stylaræa, 311.
Stylaster, 225, 226.
Stylasteridæ, 225.
Stylina, 272.
Styliola, 805.
Styliola-limestone, 805, 806.
Stylodictya, 148, 149.
Stylommatophora, 811.
Stylonurus, 554, 555.
Stylophora, 244, 245, 268.
Subulites, 786, 787.
Subulitidæ, 786.
Succession of organic types, 96.
Succinea, 813.
Suessia, 665.
Sulcator, burrows of, 488.
Sulcuna, 508.
Sulphate of lime, 14.
Sycon, 179.
Sycones, 179.
Syconidæ, 179.
Symbathocrinidæ, 432.
Symbathocrinus, 432.
Synapta, 406, 407.
Synaptychus, 851.
Synhelia, 267, 268.
Synocladia, 628.
Syringammina, 127.
Syringolites, 318, 319.
Syringophyllum, 322.
Syringopora, 319, 321, 322.
Syringoporidæ, 319, 320, 321.
Syringosphæra, 227, 229.
Syringosphæridæ, 229.
Syringothyris, 665.

Tabulate Corals, 264.
Tæniaster, 405.
Talitrus, 556.
Tancredia, 739.
Tancredidæ, 739.
Tapes, 737.
Taxocrinidæ, 431.
Taxocrinus, 431, 445.
Tectibranchiate Gastropods, 800.
Teichonidæ, 179.
Tellina, 747.
Tellinacea, 747.
Tellinidæ, 747.
Tellinomya, 716, 717.
Temnechinus, 382.
Temnocheilus, 846.
Tenebrionidæ, 601.
Tentaculites, 808, 809, 810.
Tentaculitidæ, 808.
Terebellum, 790.
Terebra, 799.
Terebratella, 675.
Terebratula, 673, 674.
Terebratulidæ, 673.
Terebratulina, 674.
Terebridæ, 799.
Terebrirostra, 675.
Teredina, 745.
Teredinidæ, 745.
Teredo, 745, 746.
Termites, 597.
Terquemia, 699.
Tessellate Crinoids, 423, 424.
Testacella, 811.
Testacellidæ, 811.
Tethya, 163.
Tethyopsis, 164.
Tetrabranchiate Cephalopods, 826.
Tetracidaris, 378, 379.
Tetracladina, 165.
Tetracoralla, 276.
Tetractinellidæ, 163.
Tetradiidæ, 340.
Tetradium, 340, 341.
Tetragonis, 172.
Tetragraptus, 217.
Tetraprionidian Graptolites, 220.
Textularia, 130.
Textularidæ, 122, 130.
Thalaminia, 199.
Thalassicolla, 144.
Thalassolampe, 144.
Thamnograptus, 205.
Thaumatocrinus, 438, 443.
Theca, 807.
Thecaphora, 197, 203.
Thecia, 322, 323.
Thecidæ, 322, 323.
Thecidea, 678.
Thecidiidæ, 677.
Thecidium, 677, 678.
Thecocyathus, 266.
Thecopsammia, 308.
Thecosmilia, 270, 272.
Thecosomatous Pteropods, 803, 804.
Thecostegites, 322.
Thelyphonus, 580.
Theonoidæ, 620.
Thetis, 738.
Thinning out of beds, 72.
Thiollericrinus, 442, 443.
Tholiasterella, 178.
Thoracica (*Cirripedia*), 497.
Thoracostraca, 559.
Thracia, 749.
Thyonidium, 406, 407.
Thysanura, 592.
Tiaracrinus, 452.
Tinoporus, 133.
Titanophasma, 594.
Tityus, 579.

Tornatella, 801.
Tornatellidæ, 800.
Toulminia, 175.
Toxoceras, 869.
Trachyceras, 857.
Trachyderma, 475.
Trachymedusæ, 205.
Trachynemidæ, 206.
Trachynemites, 206.
Trachypora, 315.
Tracks of Annelides and Molluscs, 480, 484.
Trapezium, 736.
Trematobolites, 175.
Tremacystia, 180.
Tremadictyon, 174.
Tremanotus, 769.
Trematis, 651, 653.
Trematodiscus, 149, 846.
Trematospira, 668.
Tretenterata (*Brachiopoda*), 649.
Triacrinus, 432.
Triæna, 600.
Triarthrus, 532.
Trichites, 710.
Trichoptera, 597, 598
Tricœlocrinus, 463.
Tridacna, 727.
Tridacnidæ, 727.
Triforis, 789.
Trigonellites, 851.
Trigonia, 719, 720.
Trigoniidæ, 719.
Trigonodus, 722.
Trigonosemus, 675.
Trilobita, 516.
Trimerella, 654, 655.
Trimerellidæ, 654.
Trimerocephalus, 541.
Trinucleidæ, 544.
Trinucleus, 544, 545.
Triplesia, 670.
Tripoli, 33, 1490.
Trivia, 791.
Triton, 793.
Tritonium, 793.
Tritoniidæ, 792.
Trochammina, 129.
Trochidæ, 774.
Trochobolus, 174.
Trochoceras, 844.
Trochoceratidæ, 844.
Trochocyathus, 266.
Trochocystites, 451.
Trocholites, 844.
Trochonema, 776.
Trochoseris, 304.
Trochosmilia, 270.
Trochotoma, 767.
Trochus, 774.
Troostoblastidæ, 463.
Troostocrinus, 463.
Trophon, 796.
Tropidaster, 399.
Tropidoleptus, 661.
Tropites, 856.
Tropitidæ, 856.
Truncatella, 786.
Truncatellidæ, 786.
Truncatulina, 133.
Tryblidium, 762, 763.
Tubicolous Annelides, 471.
Tubipora, 326, 328, 329, 330.
Tubiporidæ, 326, 328.
Tubularian Zoophytes, 197.
Tubulipora, 616.
Tubuliporidæ, 616.
Tubulosa, 264.
Tudicla, 796.
Tunicata, 603.
Turbinaria, 310.
Turbinella, 795.
Turbinidæ, 775.
Turbinolia, 266.
Turbinolidæ, 265.
Turbo, 775.
Turbonilla, 784.
Turricula, 797.
Turrilepas, 500, 501, 502.
Turrilites, 860, 861, 862.
Turritella, 782, 783.
Turritellidæ, 782.
Tylostoma, 779.
Typhis, 796, 797.

Umbonium, 775.
Umbrella, 802.
Uncites, 667, 668.
Unconformability of strata, 69, 70.
Ungulina, 739.
Ungulinidæ, 738.
Unicardiidæ, 739.
Unicardium, 739.
Unio, 721.
Unionidæ, 720.
Unitrypa, 626.
Uraster, 399.
Urasterella, 396.
Urda, 559.

Vaginulina, 131.
Valenciennesia, 815.
Valvata, 780.
Valvular pyramid of Cystideans, 449.
Valvulina, 129.
Vanikoro, 779.
Vanuxemia, 714.
Velates, 777.
Velutina, 765.
Velutinidæ, 765.
Venericardia, 723.
Veneridæ, 737.
Venerupis, 737.
Ventriculites, 175.
Ventriculitidæ, 174, 175.
Venus, 737.
Vermes, 468.
Vermetidæ, 782.
Vermetus, 783.
Vermilia, 472.
Verruca, 499, 500.
Verrucidæ, 499.

Verrucocœlia, 174.
Verruculina, 167.
Verticillites, 180.
Vestinautilus, 846.
Vetulina, 165, 167.
Vinculuria, 635.
Vinculariidæ, 635.
Vioa, 162.
Vivipara, 780.
Voluta, 797.
Volutidæ, 796.
Volutilithes, 797.
Volutomitra, 797.
Vulsella, 703, 704.

Waldheimia, 642, 645, 646.
Websteria, 328.
White Ants, 597.
Willemoësia, 564.

Xanthilites, 567.
Xantho, 567.
Xanthopsis, 567.
Xenaster, 397.
Xenoneura, 594.
Xenophora, 776.
Xenophoridæ, 776.
Xiphosura, 546.
Xiphoteuthis, 878.
Xylobius, 584, 585.
Xylophaga, 745.
Xylophagella, 745.

Yoldia, 717.

Zaphrentidæ, 294.
Zaphrentis, 247, 262, 277, 281, 282, 283, 293, 294.
Zaphrentoidea, 284, 293.
Zeacrinus, 436.
Zeilleria, 674.
Zethus, 539.
Zoantharia, 261; *Z. malacodermata*, 263; *Z. sclerobasica*, 263; *Z. sclerodermata*, 263.
Zonites, 812.
Zoocapsa, 499.
Zygospira, 669.

II.

INDEX TO VERTEBRATA.

Abderites, 1268.
Acanthaspis, 965.
Acanthias, 929.
Acanthobatis, 934.
Acanthodea, 965.
Acanthoderma, 1015.
Acanthodes, 966.
Acanthodidæ, 966.
Acanthodopsis, 966.
Acantholepis, 965.
Acanthopholis, 1161.
Acanthopleurus, 1015.
Acanthopsis, 1000.
Acanthopterygii, 1005.
Acanthurus, 1010.
Acanus, 1013.
Accipitres, 1239.
Acdestis, 1268.
Acentrophorus, 982.
Aceratherium, 1367.
Achænodon, 1323.
Acheloma, 1032.
Achelonia, 1103.
Achyrodon, 1276.
Acichelyidæ, 1102.
Acichelys, 1103.
Acipenser, 975.
Acipenseridæ, 974.
Acipenseroidea, 974.
Aciprion, 1139.
Acodus, 921.
Acomys, 1418.
Acotherulum, 1332.
Acrodus, 942.
Acrogaster, 1011.
Acrognathus, 994.
Acrolepis, 978.
Acronuridæ, 1010.
Acrosaurus, 1137.
Acrotemnus, 984.
Acteosaurus, 1143.
Actinobatis, 933.
Actinodon, 1031.
Adapis, 1466.
Addax, 1348.
Adenoderma, 1025.
Adeotherium, 1329.
Adiposorex, 1459.
Adiposoricidæ, 1459.
Adiposoriculus, 1459.
Adocidæ, 1106.
Adocus, 1106.
Adriosaurus, 1139.
Æchmodus, 982.
Æluroictis, 1446.
Ælurodon, 1433.
Ælurogale, 1446.
Æluropsis, 1445.
Ælurosaurus, 1058, 1569.
Ælurus, 1430.
Æolodon, 1189.
Æpichthys, 1009.
Æpyornis, 1225.
Æpyornithes, 1225.
Æpyornithidæ, 1225.
Æpyprymnus, 1286.
Æpysaurus, 1179.
Æthalion, 989.
Aëtobatis, 936.
Aëtosauria, 1182.
Aëtosauridæ, 1182.
Aëtosaurus, 1137, 1182.
Agama, 1139.
Agamidæ, 1139.
Agassizia, 989.
Agathaumas, 1154.
Aglossa, 1043.
Agnopterus, 1238.
Agomphus, 1106.
Agriochœrus, 1328.
Aipichthys=*Æpichthys*.
Aïstopoda, 1024.
Alachtherium, 1424.
Alactaga, 1416.
Alastor, 1461.
Alaudidæ, 1242.
Alauda, 1242.
Alca, 1232.

Alcedinidæ, 1242.
Alcelaphus, 1347.
Alces, 1341.
Alcidæ, 1232.
Alectorides, 1233.
Aletornis, 1233.
Alligator, 1196.
Allodon, 1270.
Allolepidotus, 982.
Allomys, 1421.
Allopleuron, 1116.
Allops, 1374.
Allosaurus, 1168.
Alopecias, 945.
Alosa, 996.
Alytes, 1043, xi.
Amblotherium, 1276.
Amblyctonus, 1453.
Amblypharyngodon, 1001.
Amblypoda, 1383.
Amblypristis, 931.
Amblypterus, 978.
Amblyrhiza, 1415.
Amblystoma, 1041.
Amblyurus, 983.
Amia, 991.
Amiidæ, 990.
Amioidea, 988.
Amiopsis, 991.
Amphibamus, 1024.
Amphibia, 1018.
Amphicetus, 1304.
Amphichelydia, 1091.
Amphicœlias, 1173.
Amphicotylus, 1191.
Amphictis, 1438.
Amphicynodon, 1436.
Amphicyon, 1434.
Amphidozotherium, 1458.
Amphiemys, 1106.
Amphilestes, 1274.
Amphiperatherium, 1281.
Amphiplaga, 1014.
Amphirana, 1044.
Amphisaurus, 1166.
Amphisile, 1005.
Amphisorex, 1457.
Amphistium, 1008.
Amphitheriidæ, 1273.
Amphitherium, 1276.
Amphitragulus, 1338.
Amphitylus, 1274.
Amphiuma, 1041.
Amphodon, 998.
Amynodon, 1365.
Amynodontidæ, 1365.
Anacanthina, 1003.
Anacodon, 1382.
Anapterus, 1001.
Anaptomorphus, 1467.
Anas, 1236.
Anatidæ, 1236.
Anchilophus, 1358.
Anchippodontidæ, 1408.
Anchippodus, 1408.
Anchippus, 1359.
Anchisauridæ, 1166.
Anchisaurus, 1166.
Anchitherium, 1358.
Ancistrodon, 1016.
Ancylopoda, 1373.
Ancylotherium, 1373.
Andrias, 1041.
Anenchylum, 1010.
Anguidæ, 1140.
Anguilla, 1002.
Anguis, 1140.
Anguisaurus, 1137.
Anisodexis, 1032.
Anisolophus, 1359.
Anisonchus, 1380.
Ankistrodon, 1167.
Anomalichthys, 965.
Anomodontia, 1053, 1569.
Anoplonassa, 1308.
Anoplosaurus, 1161.
Anoplotheriidæ, 1328.
Anoplotherium, 1328.
Anostira, 1105.
Anser, 1236.
Anseres, 1236.
Anthodon, 1056.
Anthracosauridæ, 1033.
Anthracosaurus, 1034.
Anthracotheriidæ, 1324.
Anthracotherium, 1324.
Anthropoidea, 1468.
Anthropopithecus, 1470.
Antilocapra, 1345.
Antilocapridæ, 1345.
Antilope, 1347.
Apateon, 1024.
Apateonidæ, 1024.
Apatornis, 1229.
Apatosaurus, 1173.
Aphanapteryx, 1233.
Aphelophis, 1147.
Aphelops, 1367.
Aphelosaurus, 1137.
Aphelotherium, 1466.
Apholidemys, 1105.
Aphrodediridæ, 1014.
Aphrodedirus, 1014.
Aplax, 1103.
Apocopodon, 936.
Apoda, 1039.
Apogon, 1013.
Aptenodytes, 1232.
Apterodon, 1453.
Apteryges, 1225.
Apterygidæ, 1225.
Apteryx, 1225.
Aptornis, 1233.
Aquila, 1240.
Ara, 1241.
Arapaima, 999.
Archælurus, 1446.
Archæobatis, 935.
Archæobelus, 1060.
Archæoceti, 1304.
Archæochelys, 1093.
Archæomys, 1416.

Archæopterygidæ, 1221.
Archæopteryx, 1221.
Archæotherium, 1323.
Archæus, 1008.
Archegosauridæ, 1029.
Archegosaurus, 1030.
Archichthys, 971.
Arctocyon, 1453.
Arctocyonidæ, 1453.
Arctodus, 1429.
Arctomys, 1420.
Arctosaurus, 1166.
Arctotherium, 1432.
Ardea, 1238.
Ardeidæ, 1238.
Ardeosaurus, 1137.
Argala, 1238.
Argillochelys, 1115.
Argillornis, 1239.
Argillotherium, 1453.
Argyriosus, 1010.
Aristosuchus, 1169.
Arius, 1002.
Artiodactyla, 1313.
Arvicola, 1417.
Asima, 1013.
Asineopidæ, 1014.
Asineops, 1014.
Asionidæ, 1240.
Aspidichthys, 965.
Aspidopleurus, 997.
Aspidorhynchidæ, 987.
Aspidorhynchus, 987.
Aspius, 1000.
Asteracanthus, 943.
Asterodermus, 933.
Asterodon, 986.
Asterolepididæ, 962.
Asterolepis, 962.
Asterospondyli, 937.
Asthenodon, 1276.
Athecata, 1088.
Atherina, 1006.
Atherinidæ, 1006.
Atherstonia, x.
Atherura, 1415.
Athrodon, 985.
Atlantochelys, 1090.
Atlantosauridæ, 1173.
Atlantosaurus, 1173.
Atoposaurus, 1148.
Attakeopsis, 989.
Auchenaspis, 961.
Auchenia, 1335.
Auchenoglanis, 1001.
Aulacochelys, 1118.
Aulaxinus, 1469.
Auliscops, 1005.
Aulolepis, 994.
Aulostoma, 1005.
Aves, 1208.
Axestus, 1118.

Babirusa, 1321.
Bachitherium, 1333.
Baëna, 1093.
Baënidæ, 1093.
Bagarius, 1002.
Balæna, 1302.
Balænidæ, 1302.
Balænodon, 1305.
Balænoptera, 1303.
Balænotus, 1302.
Balænula, 1302.
Balistes, 1015.
Balistidæ, 1015.
Baphetes, 1033.
Baptanodon, 1127.
Baptemys, 1106.
Baptosaurus, 1145.
Batagur, 1107.
Bathmodon, 1387.
Bathygnathus, 1166.
Bathyopsis, 1388.
Batrachiderpeton, 1024.
Batrachosaurus, 1137.
Batrachus, 1044.
Bdelostoma, 923.
Belemnobatis, 933.
Bellia, 1108.
Belodon, 1183.
Belone, 1000.
Belonorhynchidæ, 988.
Belonorhynchus, 988.
Belonostomus, 987.
Benedenius, 979.
Bernissartia, 1191.
Berycidæ, 1010.
Berycopsis, 1011.
Beryx, 1011.
Bettongia, 1286.
Bison, 1351.
Bitis, 1148.
Blastomeryx, 1342.
Blenniidæ, 1006.
Blochius, 997.
Boavus, 1147.
Boidæ, 1147.
Bolodon, 1270.
Bolodontidæ, 1270.
Bolosauridæ, 1060.
Bolosaurus, 1060.
Bombinator, 1043.
Boötherium, 1350.
Bos, 1351.
Boselaphus, 1348.
Bothremys, 1099.
Bothriceps, 1033, x.
Bothriolepis, 962.
Bothriospondylus, 1176.
Bothrolabis, 1322.
Botrophis, 1147.
Bovidæ, 1345.
Brachycyon, 1434.
Brachydectes, 1191.
Brachydiastematotherium, 1373.
Brachydirus, 964.
Brachymys, 1419.
Brachyops, 1032.
Brachytherium, 1330.
Bradypodidæ, 1299.
Bradypus, 1300.

Bramatherium, 1344.
Branchiosauria, 1023.
Branchiosauridæ, 1023.
Branchiosaurus, 1023.
Brithopus, 1061, 1570.
Brontops, 1374.
Brontosaurus, 1173.
Brontotherium, 1374.
Bubalus, 1350.
Bubo, 1241.
Bucapra, 1350.
Bucerotidæ, 1242.
Bucklandium, 1001.
Bufavus, 1043.
Bufo, 1044.
Bufonidæ, 1043.
Burtinopsis, 1303.
Buteo, 1240.
Byactinus, 951.

Cacatuidæ, 1241.
Cadurcotherium, 1365.
Cænopithecus, 1466.
Cænotheriidæ, 1330.
Cænotherium, 1330.
Caiman, 1196.
Calamagrus, 1147.
Calamodon, 1410.
Calamodontidæ, 1410.
Calamoichthys, 974.
Calamopleurus, 1005.
Calamospondylus, 1170.
Calamostoma, 1014.
Callipteryx, 1007.
Callithrix, 1469.
Callophoca, 1423.
Callopristodus, 930.
Callorhynchus, 950, 951.
Camarasaurus, 1173.
Camascelus, 1233.
Camelidæ, 1334.
Camelopardalis, 1343.
Camelus, 1335.
Campodus, 941.
Camptomus, 1268.
Camptonotus, 1159.
Camptosaurus, 1159.
Canidæ, 1430.
Canis, 1435.
Canobius, 978.
Capitodus, 1012.
Capitosaurus, 1036.
Capra, 1349.
Capreolus, 1342.
Caprovis, 1350.
Carangidæ, 1008.
Carangopsis, 1010.
Caranx, 1010.
Carcharias, 946.
Carchariidæ, 946.
Carcharodon, 945.
Carcharopsis, 944.
Cardiatherium, 1414.
Cardiodon, 1177, 1414.
Cardiomys, 1414.
Carettochelyidæ, 1101.
Carettochelys, 1101.
Cariacus, 1342.
Carinatæ, 1229.
Carine, 1241.
Carioderma, 1295.
Carnivora, 1421.
Carterodon, 1415.
Castor, 1419.
Castoridæ, 1419.
Castoroides, 1415.
Castoroididæ, 1415.
Casuariidæ, 1228.
Catapleura, 1138.
Catarractes, 1232.
Cathartes, 1239.
Cathartidæ, 1239.
Catopterus, 982.
Caturidæ, 989.
Caturus, 989.
Caudata, 1039.
Caulodon, 1176.
Cavia, 1413.
Caviidæ, 1413.
Cayluxotherium, 1456.
Cebidæ, 1469.
Cebochœrus, 1322.
Cebus, 1469.
Cenerodus, 986.
Centetodon, 1459.
Centracodon, 1459.
Centrina, 929.
Centriscidæ, 1005.
Centrolepis, 978.
Centrophorus, 928.
Cephalaspidea, 959.
Cephalaspididæ, 961.
Cephalaspis, 961.
Cephalogale, 1434.
Cephalopus, 1347.
Ceraterpeton, 1025.
Ceratochelys, 1101.
Ceratodontidæ, 953.
Ceratodus, 953.
Ceratophrys, 1044.
Ceratopidæ, 1163.
Ceratops, 1163.
Ceratoptera, 936.
Ceratosauria, 1101.
Cercopithecidæ, 1469.
Cereopsis, 1236.
Cerodon, 1413.
Cervalces, 1341.
Cervidæ, 1336.
Cervulus, 1338.
Cervus, 1338.
Cestracion, 943.
Cestraciontidæ, 940.
Cetacea, 1300.
Cetharthrosaurus, 1129, 1146.
Cetiosauridæ, 1177.
Cetiosaurus, 1178.
Cetorhinus, 946.
Cetotheriophanes, 1303.
Cetotherium, 1303.
Cetuba, 1241.
Chætodontidæ, 1013.

Chaibassia, 1109.
Chalicomys, 1420.
Chalicotheriidæ, 1372.
Chalicotherium, 1373.
Chameleon, 1142.
Chameleontidæ, 1142.
Champsodelphis, 1306.
Champsosauridæ, 1133.
Champsosaurus, 1133.
Chanos, 995.
Charadriidæ, 1233.
Charadrius, 1233.
Chauliodontia, 1033.
Chauna, 1237.
Chelodina, 1100.
Chelone, 1115.
Chelonemys, 1098.
Chelonia, 1082.
Chelonidæ, 1111.
Chelonides, 1097.
Chelotriton, 1041.
Chelydosaurus, 1031.
Chelydra, 1104.
Chelydridæ, 1104.
Chelydropsis, 1105.
Chelyidæ, 1100.
Chelys, 1100.
Chelytherium, 1096.
Chenornis, 1237.
Chilonyx, 1060, 1570.
Chiloscyllium, 944.
Chimæra, 950.
Chimæridæ, 950.
Chimeroidei, 949.
Chimeropsis, 951.
Chinchillidæ, 1414.
Chiracanthus, 966.
Chirocentridæ, 999.
Chirocentrites, 995.
Chirocentrus, 994.
Chirodopsis, 979.
Chirodus, 979.
Chirolepis, 977.
Chiromys, 1464.
Chiromystus, 999.
Chironectes, 1280.
Chiroptera, 1459.
Chirosaurus, 1038.
Chirotherium, 1038.
Chirothrix, 1006.
Chirox, 1269.
Chitra, 1118.
Chitracephalus, 1098.
Chlamydosaurus, 1140.
Chlamydoselache, 938.
Chlamydotherium, 1292.
Chœnohyus, 1321.
Chœromeryx, 1333.
Chœromorus, 1321.
Chœropotamidæ, 1322.
Chœropotamus, 1323.
Cholœpus, 1300.
Chondrenchelys, 927,
Chondrosteidæ, 976.
Chondrosteus, 976.
Choneziphius, 1306.
Chriacus, 1453.
Chromidæ, 1005.
Chronozoum, 1311.
Chrysemys, 1107.
Chrysichthys, 1002.
Chrysophrys, 1012.
Ciconiidæ, 1238.
Cimolestes, 1277.
Cimolichthys, 998.
Cimoliochelys, 1116.
Cimoliomys, 1268.
Cimoliophis, 1146.
Cimoliornis, 1201.
Cimoliosaurus, 1077, 1579.
Cimolodon, 1268.
Cinosternidæ, 1105.
Cinosternum, 1105.
Cionodon, 1154.
Circus, 1240.
Cirognathus, 1064.
Cistecephalus, 1064.
Cistudo, 1108.
Cladiodon, 1167.
Cladocyclus, 1006.
Cladodontidæ, 927.
Cladodus, 927.
Clarias, 1002.
Clastes, 988.
Clemmys, 1108.
Clepsydropidæ, 1059.
Clepsydrops, 1059.
Clepsysaurus, 1166.
Clidastes, 1143.
Climatius, 967.
Climaxodus, 929.
Clinodactyla, 1312.
Clithrolepis, 983.
Clupea, 995.
Clupeidæ, 994.
Cnemiornis, 1236.
Cobitis, 1000.
Cobus, 1347.
Coccoderma, 974.
Coccodus, 985.
Coccolepis, 978.
Coccosteidæ, 964.
Coccosteus, 964.
Cochleosaurus, 1031.
Cochliodontidæ, 939.
Cochliodus, 940.
Cocytinus, 1027.
Cœlacanthidæ, 972.
Cœlacanthus, 973.
Cœlodon, 1299.
Cœlodus, 984.
Cœlogaster, 995.
Cœlogenys, 1414.
Cœlorhynchus, 952, 1010.
Cœluridæ, 1170.
Cœlurus, 1170.
Cogia, 1305.
Colobus, 1469.
Colonoceros, 1653.
Colonodus, 969.
Colonomys, 1419.
Coloreodon, 1328.

Colossochelys, 1110.
Colpodon, 1377.
Colubridæ, 1146.
Columba, 1234.
Columbæ, 1234.
Columbidæ, 1234.
Colymboides, 1232.
Colymbosaurus, 1077.
Colymbus, 1232.
Comphotherium, 1456.
Compsemys, 1105.
Compsognathidæ, 1169.
Compsognathus, 1169.
Conchiosaurus, 1072.
Conchodus, 957.
Conchopoma, 955.
Condylarthra, 1378.
Conepatus, 1428.
Coniasaurus, 1139.
Conodonts, 921.
Conoryctes, 1453.
Contracavia, 1413.
Corax, 946.
Cordylodon, 1457.
Cormoranus, 1238.
Corvidæ, 1242.
Corvus, 1242.
Coryphænidæ, 1007.
Coryphodon, 1386.
Coryphodontia, 1385.
Coryphodontidæ, 1386.
Cosmolepis, 978.
Cosmoptychius, 977.
Cosoryx, 1345.
Cottidæ, 1006.
Cottus, 1006.
Coturnix, 1234.
Cotylopidæ, 1326.
Cotylops, 1326.
Cracidæ, 1233.
Craspedochelys, 1096.
Craspedodon, 1160.
Crassitherium, 1311.
Cratæomus, 1163.
Cremastosaurus, 1139.
Creodonta, 1449.
Creosaurus, 1168.
Cretornis, 1201.
Cricetodon, 1418.
Cricetus, 1418.
Cricodus, 970.
Cricosaurus, 1189.
Cricotus, 1027, 1032.
Crocidura, 1457.
Crocodilæmus, 1184.
Crocodilia, 1180.
Crocodilidæ, 1192.
Crocodilus, 1195.
Crocuta, 1442.
Crossognathus, 995.
Crossopholis, 975.
Crossopterygea, 968.
Crossopus, 1457.
Crotalidæ, 1148.
Cryptobranchus, 1041.
Cryptodira, 1101.
Cryptodraco, 1159.
Cryptomeryx, 1332.
Cryptoprocta, 1440.
Cryptornis, 1242.
Cryptosaurus, 1159.
Crypturi, 1231.
Crypturus, 1232.
Ctenacanthus, 968.
Ctenacodon, 1267.
Ctenodactylus, 1415.
Ctenodus, 956.
Ctenomys, 1415.
Ctenoptychius, 930.
Cumnoria, 1159.
Cuniculus, 1417.
Cyamodus, 1066.
Cyathaspis, 960.
Cybium, 1007.
Cyclanorbis, 1117.
Cyclobatis, 937.
Cycloderma, 1117.
Cyclopidius, 1327.
Cyclopoma, 1013.
Cycloptychius, 978.
Cyclostomi, 923.
Cyclotosaurus, 1036.
Cycloturus, 1295.
Cyclurus, 991, 1001.
Cycnorhamphus, 1201.
Cygnus, 1236.
Cynælurus, 1447.
Cynocephalus, 1470.
Cynochampsa, 1059, 1569.
Cynodictis, 1436.
Cynodon, 1436.
Cynodontomys, 1467.
Cynodraco, 1059, 1569.
Cynohyænodon, 1452.
Cynomys, 1420.
Cynonasua, 1429.
Cynosuchus, 1059, 1569.
Cyon, 1435.
Cyprinidæ, 1000.
Cyprinodon, 1000.
Cyprinodontidæ, 1000.
Cyprinus, 1000.
Cypselidæ, 1242.
Cypselus, 1242.
Cyrtonodus, 940.
Cystignathidæ,[1] 1044.
Cystophora, 1423.
Cyttidæ, 1007.
Cyttoides, 1007.

Dacochelys, 1100.
Dacosaurus, 1189.
Dacrytherium, 1330.
Dactylethridæ,[2] 1043.
Dactylodus, 930.
Dactylolepis, 986.
Dactylopteridæ, 1006.
Dactylopterus, 1006.

[1] = *Leptodactylidæ*. See Corrigenda.

[2] = *Xenopodidæ*. See Corrigenda.

Dactylosaurus, 1073.
Dædicurus, 1294.
Dædon, 1376.
Damonia, 1108.
Dapediidæ, 981.
Dapedius, 982.
Dapedoglossus, 999.
Daphænus, 1435.
Daptinus, 999.
Dasornis, 1229.
Dasyceps, 1034.
Dasypodidæ, 1291.
Dasypotherium, 1292.
Dasyprocta, 1414.
Dasyproctidæ, 1414.
Dasypus, 1292.
Dasyuridæ, 1278.
Dasyurodon, 1453.
Dasyurus, 1279.
Dawsonia, 1024.
Decticadapis, 1421.
Decticus, 1418.
Delphinapterus, 1307.
Delphinidæ, 1307.
Delphinus, 1307.
Deltatherium, 1453.
Deltodus, 940.
Deltoptychius, 940.
Dendrerpetidæ, 1032.
Dendrocygna, 1236.
Dendrodus, 969.
Dendrohyrax, 1383.
Dendrolagus, 1286.
Dendroptychius, 971.
Deomys, 1418.
Dercetidæ, 997.
Dercetis, 997.
Dermatemydidæ, 1106.
Dermatemys, 1106.
Dermochelyidæ, 1090.
Dermochelys, 1091.
Dermodactylus, 1201.
Desmatotherium, 1355.
Desmotylus, 1310.
Deuterosaurus, 1061, 1570.
Diacodexis, 1382.
Diadectes, 1061.
Diadectidæ, 1061, 1570.
Diadetognathus, 1037.
Diadomus, 1290.
Diadophorus, 1359.
Diatrema, 1229.
Dibelodon, 1395.
Dicentrodus, 928.
Diceratherium, 1368.
Dichobunus, 1331.
Dichodon, 1332.
Dichodontidæ, 1332.
Diclitodus, 941.
Diclonius, 1154.
Diconodon, 1374.
Dicotyles, 1322.
Dicotylidæ, 1318.
Dicrenodus, 928.
Dicroceros, 1338.
Dicrocynodon, 1277.
Dictyodus, 1007.
Dictyopyge, 982.
Dicynodon, 1063.
Dicynodontia, 1062.
Dicynodontidæ, 1063.
Didelphodon, 1277.
Didelphodus, 1453.
Didelphops, 1277.
Didelphyidæ, 1280.
Didelphys, 1280.
Dididæ, 1235.
Didus, 1235.
Didymaspis, 961.
Didymictis, 1437.
Didymodon, 1331.
Didymodus, 926.
Digerrhum, 1092.
Dilobodon, 1377.
Dilophodon, 1356.
Dilotherium, 1331.
Dimetrodon, 1059.
Dimorphodon, 1204.
Dimylidæ, 1457.
Dimylus, 1457.
Dinichthyidæ, 965.
Dinichthys, 965.
Dinictis, 1444.
Dinoceras, 1388.
Dinocerata, 1387.
Dinocyon, 1434.
Dinodocus, 1179.
Dinophis, 1148.
Dinornis, 1226.
Dinornithidæ, 1226.
Dinosauria, 1151.
Dinotheriidæ, 1393.
Dinotherium, 1393.
Diobroticus, 1419.
Diodon, 1015.
Diodontidæ, 1015.
Diomedia, 1239.
Diopecephalus, 1200.
Dioplotherium, 1311.
Diphrissa, 951.
Diplacanthus, 966.
Diplacodon, 1374.
Diplacodus, 940.
Diplarthra, 1312, 1313.
Diplobune, 1328.
Diplocynodon, 1195, 1277.
Diplodocidæ, 1176.
Diplodocus, 1176.
Diplodus, 926.
Diplognathus, 665.
Diplomystus, 996.
Diplopterus, 971.
Diplopus, 1325.
Diplospondylidæ, 1027.
Diplospondylus, 1027, 1032.
Diplovertebron, 1027.
Diplurus, 973.
Dipnoi, 952.
Dipodidæ, 1416.
Dipöides, 1416.
Dipriodon, 1268.
Dipristis, 951.

Diprotodon, 1283.
Diprotodontia, 1281.
Diprotodontidæ, 1283.
Dipteridæ, 956.
Dipterus, 956.
Diracodon, 1163.
Discoglossidæ, 1043.
Discosaurus, 1031, 1077.
Dissacus, 1453.
Dithyrosternum, 1105.
Docodon, 1277.
Dolichipterus, 1233.
Dolichosauridæ, 1142.
Dolichosaurus, 1142.
Dolichosoma, 1024.
Dolichosomatidæ, 1024.
Dolichotis, 1413.
Doliochærus, 1321.
Domnina, 1463.
Doratorhynchus, 1201.
Dorcatherium, 1333.
Dorycopteri, 991.
Dorygnathus, 1203.
Dorypteridæ, 991.
Dorypterus, 991.
Dracænosaurus, 1142.
Dremotherium, 1330.
Drepanodon, 1449.
Drepanophorus, 943.
Dromæus, 1228.
Dromatheriidæ, 1272.
Dromatherium, 1272.
Dromocyon, 1437, 1453.
Dromornis, 1228.
Dryolestes, 1276.
Dryopithecus, 1470.
Ductor, 1009.
Dules, 1013.
Duplicidentata, 1412.
Dynatobatis, 934.
Dyscanus, 1154.
Dysopes, 1462.
Dystrophæus, 1163.

Ecaudata, 1042.
Echeneis, 1007.
Echidna, 1148, 1266.
Echidnidæ, 1266.
Echinodon, 1148.
Echinogale, 1458.
Echinomys, 1415.
Echinorhinus, 929.
Ectacodon, 1387.
Ectoconus, 1380.
Ectocynodon, 1056.
Ectosteorhachis, 972.
Edaphodon, 951.
Edaphosaurus, 1056.
Edentata, 1289.
Edestosaurus, 1143.
Edestus, 947.
Egertonia, 1004.
Elachoceros, 1388.
Elaphis, 1146.
Elapidæ, 1148.
Elaps, 1148.
Elasmobranchei, 923.
Elasmodectes, 950.
Elasmodus, 951.
Elasmognathus, 950, 1354.
Elasmosaurus, 1077.
Elasmotherium, 1371.
Elephantidæ, 1394.
Elephas, 1401.
Eleutherocercus, 1294.
Elonichthys, 978.
Elopides, 996.
Elopopsis, 996.
Elops, 996.
Elorius, 1233.
Elornis, 1238.
Elotherium, 1323.
Elseya, 1100.
Emballonuridæ, 1462.
Embolophorus, 1056, 1570.
Emmenodon, 1395.
Empedias, 1061, 1062, 1570.
Empedocles, 1062.
Empo, 998.
Emyda, 1117.
Emydosauria, 1180.
Emydura, 1100.
Emys, 1108.
Enaliochelys, 1103.
Enaliornis, 1229.
Enaliosuchus, 1189.
Enchodontidæ, 997.
Enchodus, 998.
Endactis, 989.
Endothiodon, 1064.
Endothiodontidæ, 1064.
Engraulis, 995.
Enhydra, 1427.
Enhydriodon, 1427.
Enhydrocyon, 1433.
Enneodon, 1015, 1277.
Entelodon, 1323.
Entomacodon, 1459.
Entomodon, 1459.
Entoptychus, 1416.
Eobasileus, 1388.
Eohippus, 1356.
Eomys, 1419.
Eosaurus, 1037.
Eosphargis, 1090.
Eotherium, 1311.
Ephippus, 1013.
Epiblema, 1415.
Epicampodon, 1167.
Epihippus, 1358.
Episcoposaurus, 1184.
Eporeodon, 1327.
Equidæ, 1359.
Equula, 1010.
Equus, 1363.
Eretmosaurus, 1077.
Erinaceidæ, 1455.
Erinaceus, 1455.
Erisichthe, 996.
Erismatopterus, 1014.
Erithizon, 1415.
Erquelinnesia, 1113.

Erycidæ, 1147.
Eryopidæ, 1029.
Eryops, 1032.
Erythromachus, 1233.
Eryx, 1147.
Eschatius, 1335.
Esocidæ, 1000.
Esox, 1000.
Esthonyx, 1409.
Euacanthus, 947.
Eucastor, 1419.
Eucercosaurus, 1161.
Eucetus, 1305.
Euchirosaurus, 1031.
Euclastes, 1113.
Eucrotaphus, 1327.
Eugnathidæ, 986.
Eugnathus, 986.
Eumeces, 1141.
Eumylodus, 951.
Eumys, 1418.
Eupetaurus, 1420.
Eupodornithes, 1232.
Eupterornis, 1230.
Eurhinodelphis, 1307.
Eurosaurus, 1061.
Euryapteryx, 1226.
Eurycarpus, 1064.
Eurycormus, 989.
Eurygnathus, 998.
Eurylepis, 978.
Eurynotus, 979.
Eurypholis, 998.
Eurysomus, 979.
Eurysternidæ, 1102.
Eurysternum, 1103.
Eurytherium, 1328.
Euryurus, 1294.
Euscelesaurus, 1161.
Euscelidosaurus, 1161.
Eusemius, 987.
Eusmilus, 1449.
Eusthenopteron, 970.
Eusuchia, 1185.
Eutatus, 1292.
Euthacanthus, 967.
Eutheria, 1289.
Euthynotus, 989.
Exocœtoides, 1000.
Exocœtus, 1000.
Exostinus, 1140.

Falco, 1240.
Falconidæ, 1249.
Felidæ, 1443.
Felis, 1447.
Felsinotherium, 1310.
Fiber, 1417.
Fissodus, 929.
Fistularia, 1005.
Fistulariidæ, 1005.
Francolinus, 1234.
Fregatidæ, 1239.
Fregilopus, 1242.
Fringillidæ, 1242.
Fulica, 1233.
Fulicariæ, 1233.
Fuligula, 1236.

Gadidæ, 1003.
Gadus, 1003.
Galago, 1467.
Galecynus, 1437.
Galeocerdo, 946.
Galeopithecus, 1455.
Galesauridæ, 1058, 1569.
Galesaurus, 1058, 1569.
Galethylax, 1453.
Galictis, 1429.
Gallinæ, 1233.
Gallinula, 1233.
Gallus, 1234.
Ganocephala, 1021.
Ganodus, 951.
Ganoidei, 958.
Ganorhynchus, 957.
Garialis, 1193.
Garialosuchus, 1193.
Gastornis, 1228.
Gastornithes, 1228.
Gastornithidæ, 1228.
Gastrocnemus, 1007.
Gaudrya, 1031.
Gaviæ, 1232.
Gazella, 1348.
Geolabis, 1459.
Gelocus, 1332.
Gennetotheria, 1060.
Geomyidæ, 1416.
Geomys, 1416.
Geosaurus, 1189.
Geotrypus, 1458.
Gerbillus, 1418.
Gigantichthys, 999.
Gigantosaurus, 1176.
Ginglymostoma, 943.
Giraffa, 1343.
Giraffidæ, 1343.
Glaridodon, 1061, 1569.
Globicephalus, 1307.
Glossochelys, 1113.
Glossodus, 930.
Glyptocephalus, 1015.
Glyptodon, 1294.
Glyptodontidæ, 1292.
Glyptognathus, 1037.
Glyptolæmus, 972.
Glyptolepis, 969.
Glyptopomus, 972.
Glyptosauridæ, 1140.
Glyptosaurus, 1141.
Gnathorhiza, 957.
Gnathosaurus, 1189.
Gobiidæ, 1006.
Gobio, 1000.
Gobius, 1006.
Gomphotherium, 1334.
Gonatodus, 978.
Gondwanosaurus, 1032.
Gonioglyptus, 1036.
Goniognathus, 1007.
Goniopholididæ, 1189.

Goniopholis, 1191.
Goniopoda, 1151.
Gonorhynchidæ, 999.
Gonorhynchus, 999.
Gorgonops, 1059, 1569.
Goura, 1234.
Graculavus, 1229.
Graculus, 1238.
Graphiurus, 973.
Gruidæ, 1233.
Grus, 1233.
Gryphoca, 1423.
Grypotherium, 1298, 1299.
Gulo, 1429.
Gymnodontes, 1015.
Gymnoptychus, 1420, 1421.
Gymnura, 1456.
Gyparchus, 1239.
Gypsornis, 1233.
Gyracanthus, 947.
Gyrodus, 985.
Gyrolepis, 978.
Gyropleurodus, 943.
Gyroptychius, 970.
Gyrosteus, 976.

Hadrianus, 1109.
Hadrosaurus, 1153.
Hæmatosaurus, 1082.
Hainosaurus, 1144.
Halcyornis, 1242.
Halec, 994, 996.
Halecidæ, 994.
Haliaëtus, 1240.
Halianassa, 1310.
Halichœrus, 1423.
Halicore, 1309.
Halicoridæ, 1309.
Halitheriidæ, 1310.
Halitherium, 1310.
Hallopus, 1170.
Halodon, 1268.
Hapale, 1469.
Hapalemur, 1466.
Hapalidæ, 1468.
Hapalotis, 1418.
Haplacodon, 1372.
Haploconus, 1380.
Haplodontotherium, 1377.
Haplogale, 1445.
Haptodus, 1131.
Hardella, 1107.
Harpagornis, 1240.
Hatteria, 1136.
Helagrus, 1146.
Helaletes, 1355.
Helemys, 1093.
Heliarchon, 1041.
Heliastes, 1004.
Helicoceros, 1347.
Helicophora, 1347.
Heliodus, 957.
Heliscomys, 1419.
Helladotherium, 1344.
Helochelys, 1093.
Helodectes, 1062, 1570.
Helodopsis, 940.
Helodus, 939.
Hemiauchenia, 1335.
Hemicaulodon, 1311.
Hemichelys, 1101.
Hemichœrus, 1323.
Hemielopopsis, 996.
Hemiganus, 1453.
Hemilopus, 986.
Hemimeryx, 1326.
Hemipristis, 946.
Hemipsalodon, 1452.
Hemirhynchus, 1010.
Hemisaurida, 1001.
Hemithlæus, 1380.
Hemithyrsites, 1010.
Hemitrichias, 996.
Heptanchus, 938.
Heptanema, 973.
Heptodon, 1356.
Herodiones, 1238.
Herpestes, 1438.
Herpetocetus, 1304.
Herpetotherium, 1458.
Hesperomys, 1418.
Hesperornis, 1224.
Heteroborus, 1453.
Heterobranchus, 1002.
Heterocetus, 1304.
Heterohyus, 1456.
Heterolepidotus, 982.
Heteromys, 1416.
Heterostrophus, 982.
Heterosuchus, 1191.
Heterotis, 999.
Hexanchus, 938.
Hexapsephus, 1001.
Hexodon, 1380.
Himantopus, 1233.
Hipparion, 1360.
Hippidium, 1361.
Hippocampus, 1014.
Hippodactylus, 1361.
Hippohyus, 1321.
Hippopotamidæ, 1316.
Hippopotamus, 1316.
Hippotherium, 1360.
Hippotragus, 1348.
Hirundo, 1242.
Histionotus, 987.
Histiophorus, 1010.
Holacanthus, 1013.
Holaspis, 961.
Holocentrum, 1011.
Holodus, 957.
Holomeniscus, 1335.
Holophagus, 974.
Holops, 1193.
Holoptychiidæ, 968.
Holoptychius, 968.
Holosteus, 1000.
Holurus, 978.
Homacanthus, 968.
Homœolepis, 983.
Homœosauria, 1136.
Homœosauridæ, 1136.

Homœosaurus, 1137.
Homalodontotherium, 1366.
Hominidæ, 1470.
Homo, 1470.
Homocamelus, 1335.
Homonotus, 1011.
Homopus, 1109.
Homorophus, 1106.
Hoplocetus, 1305.
Hoplophoneus, 1446.
Hoplophorus, 1293.
Hoplopleuridæ, 997.
Hoplopteryx, 1011.
Hoplosaurus, 1175.
Hyæna, 1441.
Hyænarctus, 1432.
Hyænictis, 1441.
Hyænidæ, 1440.
Hyænocyon, 1433.
Hyænodon, 1450.
Hyænodontidæ, 1450.
Hybocladodus, 928.
Hybodontidæ, 940.
Hybodus, 941.
Hydaspitherium, 1344.
Hydraspis, 1100.
Hydrochœrus, 1414.
Hydromys, 1417.
Hydropelta, 1098.
Hydrornis, 1232.
Hydrosaurus, 1139.
Hylæobatrachidæ, 1040.
Hylæobatrachus, 1040.
Hylæochampsa, 1191.
Hylæochelys, 1097.
Hylæosaurus, 1160.
Hylerpeton, 1024.
Hylobates, 1470.
Hylonomus, 1027.
Hyloplesion, 1027.
Hyloplesionidæ, 1027.
Hyodectes, 1453.
Hyohippus, 1359.
Hyomoschus, 1333.
Hyopotamus, 1325.
Hyopsodontidæ, 1465.
Hyopsodus, 1465.
Hyotherium, 1321.
Hypamia, 991.
Hyperodapedon, 1134.
Hyperöodon, 1306.
Hypertragulus, 1334.
Hyphasma, 1026.
Hyporyssus, 1458.
Hyposaurus, 1190.
Hypsicormus, 989.
Hypsilophodon, 1159.
Hypsiprymnodon, 1286.
Hypsiprymnopsis, 1270.
Hypsiprymnus, 1286.
Hypsodon, 998.
Hyrachyus, 1355.
Hyracidæ, 1383.
Hyracodon, 1364.
Hyracodontotherium, 1382.
Hyracoidea, 1382.
Hyracotherium, 1356.
Hyrax, 1383.
Hystricidæ, 1415.
Hystrix, 1415.

Ibis, 1238.
Ichthyacanthus, 1032.
Ichthyodectes, 998.
Ichthyodorulites, 947.
Ichthyopsida, 911.
Ichthyopterygia, 1120.
Ichthyornis, 1231.
Ichthyornithidæ, 1231.
Ichthyosauridæ, 1124.
Ichthyosaurus, 1124.
Ichthyotomi, 926.
Icticyon, 1436.
Ictitherium, 1439.
Ictonyx, 1428.
Ictops, 1459.
Ictopsidæ, 1459.
Idiocetus, 1304.
Idiochelys, 1098.
Iguana, 1140.
Iguanidæ, 1140.
Iguanodon, 1157.
Iguanodontidæ, 1154.
Immanes, 1226.
Imogaster, 1005.
Impennes, 1232.
Inia, 1306.
Insectivora, 1454.
Interatherium, 1377.
Ischyodus, 950.
Ischypterus, 982.
Ischyrocephalus, 998.
Ischyrodon, 1080.
Ischyromyidæ, 1420.
Ischyromys, 1420.
Ischyrosaurus, 1176.
Ischnacanthus, 967.
Isectolophus, 1355.
Isocetus, 1304.
Isocolum, 989.
Isopholis, 987.
Isotænia, 951.
Isselosaurus, 1196.
Issiodoromys, 1413.
Istiœus, 1000.
Isurus, 1007.
Ixacanthus, 1308.

Jaculus, 1416.
Janassa, 929.

Kachuga, 1107.
Kurtodon, 1277.

Labrax, 1013.
Labridæ, 1004.
Labrus, 1004.
Labyrinthodon, 1037.
Labyrinthodontia, 1021.
Lacerta, 1142.
Lacertidæ, 1142.
Lacertilia, 1138.

Lagenorhynchus, 1307.
Lagomyidæ, 1413.
Lagomys, 1413.
Lagopus, 1234.
Lagostomus, 1414.
Lambdodus, 928.
Lambdotheriidæ, 1371.
Lambdotherium, 1371.
Lamna, 944.
Lamnidæ, 944.
Laniidæ, 1242.
Lanius, 1242.
Lantanotherium, 1455.
Laodon, 1276.
Laophis, 1148.
Laopithecus, 1468.
Laopteryx, 1219, 1229.
Laornis, 1229.
Laosaurus, 1159.
Laridæ, 1232.
Lariosauridæ, 1073.
Lariosaurus, 1073.
Larus, 1232.
Lates, 1013.
Latonia, 1044, xi.
Lebias, 1000.
Lecracanthus, 965.
Leedsia, 1569.
Leedsichthys, 1569.
Legnonotus, 987.
Lemmus, 1417.
Lemuravus, 1468.
Lemuridæ, 1466.
Lemuroidea, 1464.
Lepidocottus, 1007.
Lepidolemur, 1466.
Lepidopus, 1010.
Lepidosiren, 953.
Lepidosirenidæ, 953.
Lepidosteidæ, 988.
Lepidosteoidea, 980.
Lepidosteus, 988.
Lepidotidæ, 986.
Lepidotus, 986.
Leporidæ, 1412.
Lepospondyli, 1023.
Leptacanthus, 951.
Leptarctus, 1429.
Leptauchenia, 1327.
Lepterpeton, 1025.
Lepthyæna, 1441.
Leptictidæ, 1459.
Leptictis, 1459.
Leptobos, 1350.
Leptocephali, 1002.
Leptochœrus, 1323.
Leptocladus, 1276.
Leptodactylus, 1044.
Leptodon, 1373.
Leptolepididæ, 990.
Leptolepis, 990.
Leptomeryx, 1333.
Leptomylus, 951.
Leptoptilus, 1238.
Leptosoma, 1242.
Leptosomatidæ, 1242.
Leptosomus, 995.
Leptotrachelus, 997.
Leptotragulus, 1334.
Lepus, 1412.
Lestodon, 1298, 1299.
Lestophis, 1147.
Lestornis, 1225.
Lestosaurus, 1144.
Leuciscus, 1000.
Liasis, 1147.
Libys, 974.
Licaphrium, 1359.
Lichia, 1010.
Limicolæ, 1232.
Limnatornis, 1242.
Limnerpetidæ, 1026.
Limnerpeton, 1026.
Limnocyon, 1437.
Limnohyus,[1] 1372.
Limnophis, 1147.
Limnotherium, 1466.
Limosa, 1232.
Liodesmus, 989.
Liodon, 1144.
Liognathus, 965.
Liopleurodon, 1080.
Liotomus, 1268.
Lissolepis, 978.
Listriodon, 1319.
Listriodontidæ, 1318.
Lithophis, 1147.
Lithornis, 1239.
Loncheres, 1415.
Lophacanthus, 947.
Lophiochœrus, 1319.
Lophiodon, 1355.
Lophiodontidæ, 1354.
Lophiomeryx, 1332.
Lophiostomus, 987.
Lophiotherium, 1357.
Lophiurus, 991.
Lophobranchii, 1014.
Lophocetus, 1308.
Lophopsittacus, 1241.
Loxia, 1242.
Loxolophodon, 1388.
Loxomma, 1033.
Loxommatinæ, 1033.
Loxomylus, 1415.
Lutkesaurus, 1079.
Lutra, 1427.
Lutremys, 1108.
Lutrictis, 1427.
Lycaon, 1436.
Lychyæna, 1441.
Lycorus, 1435.
Lycosaurus, 1058.
Lysorophus, 1060.
Lytoloma, 1113.

Macacus, 1469.
Macellodus, 1139.

[1] *Limnotherium* in text. See Corrigenda.

Macellognathus, 1089.
Machæracanthus, 947.
Machærodus, 1449.
Machimosaurus, 1187.
Macrauchenia, 1376.
Macraucheniidæ, 1376.
Macroclemmys, 1105.
Macromerion, 1035.
Macromerosaurus, 1073.
Macrones, 1002.
Macropetalichthys, 975.
Macropodidæ, 1285.
Macropoma, 974.
Macropus, 1286.
Macrorhipis, 989.
Macrorhynchus, 1190.
Macrornis, 1230.
Macrosemius, 987.
Macrotherium, 1373.
Macrurosaurus, 1179.
Mallotus, 994.
Mammalia, 1245.
Manatidæ, 1311.
Manatus, 1311.
Manidæ, 1291.
Manis, 1291.
Manteodon, 1387.
Manuria, 1110.
Marsupialia, 1272.
Massospondylus, 1166.
Mastacomys, 1418.
Mastodon, 1395.
Mastodonsauridæ, 1035.
Mastodonsaurus, 1036.
Mauisaurus, 1077.
Megacerops, 1374.
Megadactylus, 1166, 1170.
Megalania, 1142.
Megalapteryx, 1225.
Megalichthys, 970, 972.
Megalobatrachus, 1041.
Megalochnus, 1299.
Megalonyx, 1299.
Megalops, 995.
Megalornis, 1229.
Megalosauridæ, 1167.
Megalosaurus, 1167.
Megalotherium, 1295.
Megalotriton, 1041.
Megalurus, 991.
Megamys, 1414.
Megapleuron, 955.
Megapodidæ, 1233.
Megaptera, 1303.
Megasternum, 1092.
Megatheriidæ, 1295.
Megatherium, 1295.
Megistanes, 1127.
Melanerpeton, 1024.
Meleagris, 1234.
Meles, 1428.
Melitosaurus, 1193.
Mellivora, 1428.
Mellivorodon, 1428.
Melosauridæ, 1029.
Melosaurus, 1031.
Melursus, 1431.
Menacodon, 1277.
Menaspis, 965.
Mene, 1007.
Meniscöessus, 1268.
Meniscomys, 1421.
Meniscotheriidæ, 1382.
Meniscotherium, 1382.
Menobranchus, 1041.
Menodon, 1374.
Menodontidæ, 1374.
Menodus, 1374.
Menopoma, 1041.
Menops, 1374.
Mephitis, 1428.
Mergus, 1237.
Merlucius, 1003.
Merychippus, 1360.
Merychyus, 1327.
Merycochærus, 1327.
Merycopotamidæ, 1325.
Merycopotamus, 1326.
Mesacanthus, 966.
Mesembryornis, 1229.
Mesitia, 944.
Mesocetus, 1304.
Mesodectes, 1459.
Mesodon, 985.
Mesogaster, 1006.
Mesohippus, 1358.
Mesolepis, 979.
Mesolophodus, 930.
Mesonychidæ, 1453.
Mesonyx, 1453.
Mesopithecus, 1470.
Mesoplodon, 1306.
Mesorhinus, 1376.
Mesosauridæ, 1070.
Mesosaurus, 1070.
Mesotaria, 1423.
Mesotherium, 1378.
Mesturus, 985.
Metalophodon, 1386.
Metamynodon, 1365.
Metarctus, 1433.
Metarmosaurus, 1061.
Metatheria, 1270.
Metopacanthus, 951.
Metopias, 1037.
Metriorhynchus, 1188.
Metriotherium, 1329.
Miacidæ, 1437.
Miacis, 1437.
Microbiotherium, 1268.
Microbrachidæ, 1027.
Microbrachis, 1027.
Microbrachius, 963.
Microcavia, 1413.
Microchæridæ, 1456.
Microchærus, 1456.
Microconodon, 1273.
Microdon, 985.
Microlepidoti, 989.
Microlestes, 1270.
Micromeryx, 1338.
Micronodus, 978.

Micropholis, 1032.
Microsauria, 1025.
Microsyops, 1465.
Microtherium, 1331.
Microtus, 1417.
Milvus, 1240.
Mioclænus, 1453.
Miohippus, 1359.
Miolania, 1100.
Miolaniidæ, 1100.
Miolophus, 1409.
Mionornis, 1226.
Mioplosus, 1013.
Mixodectes, 1467.
Mixosaurus, 1124.
Mixtotherium, 1329.
Mochlodon, 1160.
Molge, 1041.
Molgophidæ, 1024.
Molgophis, 1024.
Molossus, 1462.
Monachus, 1423.
Monatherium, 1423.
Monocentris, 1011.
Monoclonius, 1154.
Monocondylia, 1046.
Monodon, 1307.
Monotremata, 1265.
Morenia, 1415.
Moropus, 1299, 1373.
Morosaurus, 1179.
Morotherium, 1299, 1373.
Mosasauridæ, 1143.
Mosasaurus, 1144.
Moschus, 1342.
Mouillactherium, 1331.
Mugil, 1005.
Mugilidæ, 1005.
Multituberculata, 1266.
Murænidæ, 1002.
Muræosaurus, 1077.
Muridæ, 1416.
Mus, 1418.
Musophagidæ, 1242.
Mustela, 1428.
Mustelidæ, 1426.
Mycetes, 1469.
Mylagaulus, 1415.
Myliobatidæ, 935.
Myliobatis, 935.
Mylocyprinus, 1001.
Mylodon, 1298.
Mylognathus, 951.
Mylostoma, 957.
Myogale, 1457.
Myolagus, 1413.
Myomorphus, 1299.
Myopotamus, 1415.
Myoxidæ, 1418.
Myoxus, 1418.
Myriacanthidæ, 1568.
Myriacanthus, 951, 1568.
Myriolepis, 978.
Myripristis, 1011.
Myrmecobius, 1280.
Myrmecophaga, 1295.
Myrmecophagidæ, 1295.
Mysarachne, 1458.
Mysops, 1420.
Mystacoceti, 1302.
Mystriosaurus, 1187.
Myxene, 923.
Myxochærus, 1330.

Naia, 1148.
Naisia, 988.
Nannosuchus, 1191.
Nanomys, 1268.
Naosaurus, 1060.
Narboa, 1147.
Naseus, 1010.
Nasua, 1429.
Necrolemur, 1467.
Necromantis, 1463.
Necropsar, 1242.
Necropsittacus, 1241.
Necrornis, 1242.
Nectridea, 1025.
Nematoptychius, 978.
Nemopteryx, 1003.
Neophron, 1239.
Neoplagiaulax, 1267.
Neorhombolepis, 986.
Neosodon, 1176.
Neotoma, 1418.
Nephrotus, 986.
Nesocerodon, 1413.
Nesocia, 1418.
Nesodon, 1376.
Nestor, 1241.
Nestoritherium, 1373.
Neurodromicius, 1148.
Neurogymnurus, 1456.
Neusticosaurus, 1073.
Nicoria, 1109.
Nimravidæ, 1443.
Nimravus, 1446.
Nodosaurus, 1164.
Notæus, 991.
Notagogus, 987.
Notelephas, 1408.
Notharctus, 1466.
Nothosauridæ, 1071.
Nothosaurus, 1072, 1570.
Nothropus, 1300.
Nothrotherium, 1299.
Nothura, 1232.
Notidanidæ, 938.
Notidanus, 938.
Notiosaurus, 1142.
Notochelone, 1113.
Notochelys, 1113.
Notogoneus, 999.
Notornis, 1233.
Notosaurus, 1139.
Nototheriidæ, 1282.
Nototherium, 1282.
Numenius, 1232.
Nummopalatus, 1004.
Nuthetes, 1148.
Nyctea, 1241.
Nycticebus, 1464.

Nycticorax, 1238.
Nyctilestes, 1461.
Nyctitherium, 1461.
Nyctodactylus, 1199.
Nyrania, 1032.
Nyraniidæ, 1032.
Nyroca, 1237.
Nythetes, 1148.
Nythosaurus, 1058.

Ocadia, 1108, 1570.
Octodon, 1415.
Octodontidæ, 1415.
Octotomus, 1388.
Ocydromus, 1233.
Odontaspis, 945.
Odonteus, 1004.
Odontoceti, 1305.
Odontoglossæ, 1237.
Odontolcæ, 1224.
Odontopteryges, 1236.
Odontopteryx, 1236.
Odontormæ, 1231.
Odontornithes, 1231.
Œnoscopus, 989.
Œstocephalus, 1026.
Ogmophis, 1147.
Oligobunis, 1433.
Oligopleurus, 989.
Oltinotherium, 1323.
Omegodon, 1419.
Omomys, 1467.
Omosaurus, 1162.
Omphælodus, 986.
Onchus, 947.
Oncobatis, 934.
Onychodectes, 1453.
Onychodus, 968.
Ophichthys, 1002.
Ophiderpeton, 1024.
Ophidia, 1146.
Ophiocephalidæ, 1005.
Ophiocephalus, 1005.
Ophiopsis, 987.
Ophisaurus, 1140.
Opisthopteryx, 994.
Oplosaurus, 1175.
Opsigonus, 991.
Opthalmosaurus, 1127.
Oracanthus, 947, 1296.
Orca, 1307.
Orcynus, 1007.
Oreas, 1348.
Oreodon, 1326.
Oreodontidæ, 1326.
Oreodus, 940.
Oreopithecus, 1470.
Orcosaurus, 1141.
Orinosaurus, 1161.
Ornithischia, 1151.
Ornithocephalus, 1200.
Ornithochirus, 1201.
Ornithodesmus, 1204.
Ornithopoda, 1152.
Ornithopsis, 1175.
Ornithopterus, 1204.
Ornithorhynchidæ, 1265.
Ornithorhynchus, 1265.
Ornithosauria, 1196.
Ornithostoma, 1199.
Orodontidæ, 940.
Orodus, 940.
Orohippus, 1356.
Orophosaurus, 1082.
Orosaurus, 1161.
Orthacanthus, 926.
Orthacodus, 945.
Orthagoriscus, 1015.
Orthaspidotherium, 1288, 1457.
Orthocosta, 1027.
Orthocynodon, 1365.
Orthomerus, 1154.
Orthomys, 1415.
Orthopoda, 1151.
Orthopus, 1061.
Orycterocetus, 1308.
Orycteropodidæ, 1290.
Orycteropus, 1290.
Oryx, 1348.
Osmeroides, 994.
Osmerus, 994.
Osteoglossidæ, 999.
Osteoglossum, 999.
Osteolepididæ, 971.
Osteolepis, 971.
Osteophorus, 1031.
Osteopygis, 1113.
Ostracion, 1015.
Otaria, 1424.
Otariidæ, 1424.
Otididæ, 1233.
Otis, 1233.
Otocyon, 1436.
Otodus, 944.
Oudenodon, 1064.
Ovibos, 1350.
Ovis, 1350.
Owenia, 1283.
Oweniasuchus, 1191.
Oxacrion, 1331.
Oxhyæna, 1451.
Oxydondotherium, 1376.
Oxyglossus, 1044.
Oxygnathus, 978.
Oxyrhina, 944.

Pachyacanthus, 1311.
Pachycormidæ, 989.
Pachycormus, 989.
Pachycynodon, 1436.
Pachynolophus, 1356.
Pachypleura, 1073.
Pachyrhizodontidæ, 998.
Pachyrhizodus, 998.
Pachyrucus, 1378.
Paciculus, 1418.
Pagellus, 1012.
Palædaphus, 957.
Palæeudyptes, 1232.
Palæhoplophorus, 1294.
Palælodus, 1237.
Palæobalistum, 984.

Palæobatis, 941.
Palæobatrachidæ, 1043, xi.
Palæobatrachus, 1043.
Palæocastor, 1420.
Palæocetus, 1303.
Palæochelys, 1108, 1570.
Palæochœrus, 1321.
Palæociconia, 1238.
Palæocircus, 1240.
Palæocyon, 1436.
Palæoerinaceus, 1456.
Palæogadus, 1003.
Palæogale, 1428.
Palæogrus, 1233.
Palæohatteria, 1132.
Palæohatteriidæ, 1132.
Palæohierax, 1240.
Palæolagus, 1412.
Palæolemur, 1466.
Palæomanis, 1291.
Palæomedusa, 1103.
Palæomephitis, 1428.
Palæomeryx, 1338.
Palæonictis, 1453.
Palæoniscidæ, 976.
Palæoniscus, 977.
Palæonycteris, 1461.
Palæoperdix, 1234.
Palæophidæ, 1147.
Palæophis, 1147.
Palæophoca, 1423.
Palæophrynus, 1044.
Palæopontoporia, 1306.
Palæoprionodon, 1439.
Palæopython, 1147.
Palæoreas, 1348.
Palæorhynchidæ, 1010.
Palæorhynchus, 1010.
Palæornis, 1201, 1241.
Palæornithidæ, 1241.
Palæortyx, 1234.
Palæoryx, 1348.
Palæosaurus, 1167.
Palæoscyllium, 943.
Palæosiren, 1024.
Palæospalax, 1457.
Palæospinax, 943.
Palæospiza, 1242.
Palæosyops, 1372.
Palæotapirus, 1354.
Palæotheriidæ, 1357.
Palæotherium, 1357.
Palæotheutes, 1268.
Palæotragus, 1349.
Palæotringa, 1229.
Palæovaranus, 1140.
Palamedeæ, 1237.
Palapterygidæ, 1226.
Palapteryx, 1226.
Palauchenia, 1335.
Paleryx, 1147.
Palhyæna, 1441.
Palimphyes, 1007.
Paloplotherium, 1357.
Palorchestes, 1287.
Pandion, 1240.
Pangshura, 1107.
Panochthus, 1294.
Panolax, 1412.
Pantodonta, 1385.
Pantolambda, 1385.
Pantolambdidæ, 1385.
Pantolestes, 1315.
Pantylus, 1056.
Pappichthys, 991.
Parachelyidæ, 1097.
Parachelys, 1097.
Paradoxurus, 1438.
Parahippus, 1359.
Parahyus, 1323.
Paralepis, 1001.
Paramys, 1420.
Paraperca, 1013.
Parascopelus, 1001.
Parasorex, 1455.
Parasuchia, 1183.
Parasuchidæ, 1184.
Parasuchus, 1184.
Paratheria, 1289.
Parexus, 967.
Pariasauria, 1055.
Pariasauridæ, 1055.
Pariasaurus, 1055.
Pariotichidæ, 1056.
Pariotichus, 1056.
Passer, 1242.
Passeres, 1242.
Patriofelis, 1453.
Pediomys, 1277.
Pelagorhynchus, 997.
Pelagornis, 1239.
Pelagosaurus, 1187.
Pelamys, 1007.
Pelecanidæ, 1239.
Pelecanus, 1239.
Pelecopterus, 997.
Pelion, 1024.
Pellegrinia, 1415.
Pelobates, 1043.
Pelobatidæ, 1043.
Pelobatochelys, 1103.
Pelomedusidæ, 1099.
Pelonax, 1323.
Peloneustes, 1080.
Pelophilus, 1043.
Pelorosaurus, 1175.
Peltochelys, 1105.
Peltopleurus, 987.
Peltosaurus, 1140.
Pelycodus, 1465.
Pelycosauria, 1057.
Peplorhina, 969.
Peragale, 1280.
Peralestes, 1277.
Perameles, 1280.
Peramelidæ, 1280.
Peramus, 1276.
Peraspalax, 1276.
Peratherium, 1281.
Perca, 1013.
Perchœrus, 1323.
Percidæ, 1013.

Periops, 1146.
Periptychidæ, 1379.
Periptychus, 1379.
Perissodactyla, 1352.
Petalodontidæ, 929.
Petalodus, 930.
Petalorhynchus, 929.
Petrogale, 1287.
Petromyzon, 923.
Petrophryne, 1032.
Petrosuchus, 1190.
Pezophaps, 1235.
Phacochœridæ, 1318.
Phacochœrus, 1320.
Phœnicopteridæ, 1237.
Phœnicopterus, 1237.
Phalacrocoracidæ, 1238.
Phalacrocorax, 1238.
Phalangeridæ, 1284.
Phaneroglossa, 1043.
Phaneromeryx, 1333.
Phaneropleuridæ, 955.
Phaneropleuron, 955.
Phanerosaurus, 1062.
Phanerosteon, 978.
Pharyngodopilidæ, 1004.
Pharyngodopilus, 1004.
Pharyngognathi, 1004.
Phascolarctus, 1284.
Phascolestes, 1276.
Phascolomyidæ, 1282.
Phascolomys, 1282.
Phascolonus, 1282.
Phascolotherium, 1274.
Phasianidæ, 1234.
Phasianus, 1234.
Phenacodontidæ, 1380.
Phenacodus, 1380.
Phloramys, 1415.
Phoca, 1423.
Phocanella, 1423.
Phocasaurus, 1057.
Phocidæ, 1423.
Phoderacanthus, 965.
Phœbodus, 928.
Phœnicopteridæ, 1237.
Phœnicopterus, 1237.
Pholidophorus, 987.
Pholidopleurus, 987.
Pholidosaurus, 1190.
Pholidurus, 976.
Phylactocephalus, 998.
Phyllodus, 1004.
Phyllolepis, 969.
Phyllomys, 1415.
Phyllorhina, 1461.
Phyllostoma, 1463.
Phyllostomatidæ, 1462.
Physeter, 1305.
Physeteridæ, 1305.
Physeterula, 1305.
Physetodon, 1305.
Physis, 1003.
Physodon, 1305.
Physostomi, 993.
Phytosauria, 1183.
Phytosauridæ, 1183.
Phytosaurus, 1183.
Picariæ, 1242.
Picidæ, 1242.
Picus, 1242.
Pilemophis, 1146.
Pimelodus, 1002.
Pinnipedia, 1422.
Pipidæ, 1043.
Piptomerus, 1082.
Pisces, 911.
Pistosaurus, 1072.
Pithanotomys, 1415.
Pithecistes, 1327.
Placodermata, 962.
Placodontia, 1065.
Placodus, 1066.
Placosauridæ, 1140.
Placosaurus, 1140.
Plagiaulacidæ, 1267.
Plagiaulax, 1267.
Plagiolophus, 1357.
Plastomenus, 1118.
Plastremys, 1098.
Plataleidæ, 1238.
Platanista, 1306.
Platanistidæ, 1306.
Platax, 1009.
Platemys, 1100.
Plateosaurus, 1167.
Platinx, 995.
Platycarpus, 1143.
Platyceps, 1033.
Platycercomys, 1416.
Platychelys, 1093.
Platychœropidæ, 1409.
Platychœrops, 1409, 1453.
Platycormus, 1013.
Platygnathus, 969.
Platygonus, 1323.
Platylæmus, 1005.
Platyonyx, 1296.
Platyoposaurus, xi.
Platyops, 1035.
Platyphoca, 1423.
Platypodosaurus, 1064.
Platyprosopus, 1338.
Platyrhachis, 1139.
Platysiagum, 987.
Platysomidæ,[1] 979.
Platysomus, 980.
Platysternidæ, 1106.
Platysternum, 1106.
Plectognathi, 1014.
Plegothonidæ, 1024.
Plegothontia, 1024.
Plesiadapis, 1467.
Plesiarctomys, 1420.
Plesictis, 1429.
Plesidacrytherium, 1330.
Plesiocetopsis, 1303.
Plesiocetus, 1303.

[1] = *Platysomatidæ*. See Corrigenda.

Plesiochelyidæ, 1096.
Plesiochelys, 1096.
Plesiogale, 1428.
Plesiomeryx, 1331.
Plesiosauridæ, 1074.
Plesiosaurus, 1075.
Plesiosorex, 1458.
Plesiospermophilus, 1421.
Plestiodon, 1041.
Pleuracanthidæ, 926.
Pleuracanthus, 926.
Pleuraspidotherium, 1288, 1457.
Pleurocœlus, 1179.
Pleurodira, 1094.
Pleurodus, 939, 1066.
Pleurolepis, 983.
Pleurolichus, 1416.
Pleuronectidæ, 1003.
Pleuronura, 1023.
Pleuropholis, 987.
Pleuroplax, 939.
Pleurosauridæ, 1137.
Pleurosaurus, 1137.
Pleurosternidæ, 1092.
Pleurosternum, 1092.
Pliauchenia, 1335.
Plinthophorus, 997.
Pliohippus, 1361.
Pliolophus, 1356.
Plionemus, 1009.
Plioparchus, 1014.
Pliopithecus, 1470.
Plioplatycarpidæ, 1143.
Plioplatycarpus, 1143.
Plioprion, 1267.
Pliosaurus, 1080.
Plotidæ, 1238.
Plotus, 1238.
Pneumatosteus, 988.
Pnigeacanthus, 965.
Podocnemis, 1100.
Podocys, 1013.
Poëbrotheriidæ, 1334.
Poëbrotherium, 1334.
Pœcilia, 1000.
Pœcilodus, 940.
Pogonodon, 1446.
Polacanthus, 1161.
Polycotylus, 1077.
Polymastodon, 1269.
Polymastodontidæ, 1269.
Polyodon, 975.
Polyonax, 1163.
Polyplocodus, 970.
Polyprotodontia, 1272.
Polypteridæ, 974.
Polypterus, 974.
Polyptychodon, 1079.
Polyrhizodus, 930.
Polythorax, 1093.
Pomacanthus, 1013.
Pomacentridæ, 1004.
Pomognathus, 998.
Pontistes, 1306.
Pontoporia, 1306.
Porphyrio, 1233.
Portheus, 998.
Potamarchus, 1414.
Potamochœrus, 1319.
Potamotherium, 1427.
Potorous, 1286.
Priacodon, 1277.
Primates, 1463.
Priodontognathus, 1161.
Prionodon, 1438.
Prionodus, 921.
Priscacara, 1004.
Priscodelphinus, 1308.
Pristidæ, 931.
Pristigenys, 1011.
Pristiophoridæ, 931.
Pristiophorus, 931.
Pristipoma, 1014.
Pristipomatidæ, 1014.
Pristis, 931.
Pristiurus, 944.
Pristodontidæ, 930.
Pristodus, 930.
Proælurus, 1444.
Probatrachus, 1043.
Proboscidea, 1390.
Probubalus, 1350.
Procamelus, 1334.
Procardiatherium, 1414.
Procellariidæ, 1232.
Procolophon, 1065.
Procolophonia, 1065.
Procolophonidæ, 1065.
Procoptodon, 1287.
Procynictis, 1288.
Procyon, 1429.
Procyonidæ, 1429.
Prodidelphia, 1273.
Prodremotherium, 1333.
Proechidna, 1266.
Proganochelyidæ, 1096.
Proganochelys, 1096.
Proganosauria, 1071.
Prognathodus, 951.
Progoura, 1234.
Prohalecites, 987.
Prohalicore, 1309.
Prohyæna, 1433.
Promephitis, 1428.
Prominatherium, 1324.
Propalæotherium, 1357.
Propappus, 1056.
Prophoca, 1423.
Propithecus, 1466.
Propleura, 1113.
Propristis, 931.
Propseudopus, 1140.
Propterus, 987.
Prorastomus, 1310.
Protacanthodes, 1015.
Protagrus, 1147.
Protalpa, 1458.
Protamia, 991.
Protapirus, 1356.
Protauchenia, 1335.
Protautaga, 1004.
Protechinomys, 1416.

Proteidæ, 1041.
Protelopis, 996.
Proterosauria, 1130.
Proterosaurus, 1130.
Proterotheriidæ, 1359.
Proterotherium, 1329, 1359.
Proteus, 1041.
Prothyracodon, 1355.
Protobalistum, 1015.
Protochelys, 1094.
Protodonta, 1272.
Protogonia, 1382.
Protohippus, 1360.
Protolabis, 1334.
Protomeryx, 1333.
Protopelobates, 1043.
Protophrynus, 1044.
Protopirata, 948.
Protopithecus, 1469.
Protopsalis, 1452.
Protopterus, 953.
Protoreodon, 1328.
Protornis, 1242.
Protosphargis, 1089.
Protosphyræna, 996.
Protosphyrænidæ, 996.
Protostega, 1089, 1570.
Protostegidæ, 1089.
Prototheria, 1263.
Protoxodon, 1377.
Protragelaphus, 1348.
Protragoceros, 1348.
Protriton, 1023.
Protritonidæ, 1023.
Protopelobates, 1043.
Protypotherium, 1378.
Proviverra, 1452.
Proviverridæ, 1452.
Psammochelys, 1096.
Psammodontidæ, 934.
Psammodus, 934.
Psephoderma, 1089, 1570.
Psephodus, 934.
Psephophorus, 1091.
Psephurus, 975.
Pseudælurus, 1445.
Pseudamphicyon, 1434.
Pseudoberyx, 1011.
Pseudochirus, 1285.
Pseudocyon, 1433.
Pseudoeliginus, 1007.
Pseudolestodon, 1298.
Pseudopterodon, 1451.
Pseudopus, 1140.
Pseudorca, 1307.
Pseudorhinolophus, 1461.
Pseudosciurus, 1421.
Pseudotomus, 1420.
Pseudotrionyx, 1105.
Pseudotropius, 1002.
Pseudovomer, 1008.
Psittaci, 1241.
Psittacidæ, 1241.
Psittacotherium, 1409.
Psittacus, 1241.
Ptenodraco, 1200.
Ptenornis, 1230.
Pteranodon, 1199.
Pteranodontia, 1198.
Pteranodontidæ, 1199.
Pteraspididæ, 960.
Pteraspis, 960.
Pterichthys, 962.
Pterocles, 1234.
Pteroclidæ, 1234.
Pterodactylidæ, 1199.
Pterodactylus, 1200.
Pterodon, 1451.
Pteroplax, 1037.
Pteropodidæ, 1460.
Pterosauria, 1199.
Pterycollasaurus, 1145.
Pterygocephalus, 1006.
Pterygopterus, 987.
Ptilodus, 1267.
Ptyas, 1146.
Ptychodus, 936.
Ptychogaster, 1109.
Ptychognathus, 1063.
Ptycholepis, 987.
Ptychosiagum, 1063.
Ptyctodus, 952.
Ptyoniidæ, 1025.
Ptyonius, 1026.
Ptyonodus, 957.
Puffinus, 1232.
Pugmeodon, 1310.
Puppigerus, 1113.
Putorius, 1428.
Pycnodontidæ, 983.
Pycnodus, 984.
Pycnosterinx, 1005.
Pygæus, 1014.
Pygopodes, 1232.
Pygopterus, 978.
Python, 1147.
Pythonidæ, 1146.
Pythonomorpha, 1143.
Pyxis, 1109.

Quercitherium, 1453.

Raia, 933.
Raiidæ, 933.
Rallidæ, 1233.
Rallus, 1233.
Rana, 1044.
Ranavus, 1044.
Rangifer, 1341.
Ranidæ, 1044.
Raphiosaurus, 1139.
Ratitæ, 1222.
Regnosaurus, 1161.
Remiornis, 1230.
Reptilia, 1046.
Rhabdolepis, 977.
Rhabdosteus, 1308.
Rhacheosaurus, 1189.
Rhacolepis, 996.
Rhadinacanthus, 976.
Rhadinichthys, 978.
Rhagatherium, 1330.

Rhamphocephalus, 1203.
Rhamphorhynchidæ, 1201.
Rhamphorhynchus, 1202.
Rhamphosuchus, 1193.
Rhamphosus, 1005.
Rhea, 1228.
Rheæ, 1228.
Rheidæ, 1228.
Rhina, 931.
Rhineastes, 1002.
Rhinellus, 995.
Rhinobatidæ, 933.
Rhinobatus, 933.
Rhinoceros, 1366.
Rhinocerotidæ, 1364.
Rhinochelys, 1098.
Rhinognathus, 945.
Rhinolophidæ, 1461.
Rhinolophus, 1461.
Rhinoptera, 936.
Rhinosaurus, 1033, 1144.
Rhiptoglossa, 1142.
Rhizodontidæ, 969.
Rhizodopsis, 971.
Rhizodus, 970.
Rhizomys, 1416.
Rhizoprion, 1307.
Rhodeus, 1000.
Rhomaleosaurus, 1079.
Rhombodipteridæ, 971.
Rhomboptyckius, 971.
Rhombus, 1004.
Rhopalodon, 1061.
Rhynchocephalia, 1131.
Rhynchodes, 952.
Rhynchodontidæ, 987.
Rhynchorhinus, 1002.
Rhynchosauridæ, 1134.
Rhynchosaurus, 1135.
Rhynchotus, 1232.
Rhytidosteus, 1032.
Rhytina, 1311.
Rhytinidæ, 1311.
Rhytiodus, 1311.
Ribodon, 1356.
Ricnodon, 1027.
Rita, 1002.
Rodentia, 1411.
Rupicapra, 1348.

Saiga, 1347.
Salamandra, 1041.
Salamandridæ, 1041.
Salmonidæ, 994.
Samotherium, 1345.
Sandalodus, 939.
Sanitherium, 1321.
Saniva, 1141.
Sapheosaurus, 1137.
Sarcophilus, 1279.
Sarcothraustes, 1453.
Sardinius, 994.
Sardinoides, 994.
Sargodon, 986, 1013.
Sargus, 1012.
Sauranodon, 1127.
Saurichthys, 988.
Sauridæ, 981.
Saurillus, 1139.
Saurischia, 1151.
Saurocephalidæ, 998.
Saurocephalus, 998.
Saurodon, 999.
Saurodontidæ, 986, 998.
Sauropleura, 1026.
Sauropoda, 1170.
Sauropsidæ, 1046.
Sauropsis, 989.
Sauropterygia, 1067.
Saurorhamphus, 997.
Saurosternum, 1137.
Saururæ, 1221.
Saurus, 1001.
Scaldicetus, 1305.
Scalibrinitherium, 1376.
Scaloposaurus, 1059.
Scapanorhynchus, 945.
Scaphaspis, 960.
Scaphirhynchus, 975.
Scaphognathus, 1202.
Scaptophis, 1147.
Scatophagus, 1013.
Scelidosauridæ, 1160.
Scelidosaurus, 1160.
Scelidotherium, 1296.
Sceparnodon, 1282.
Schistopleurum, 1294.
Schizodelphis, 1306.
Sciænurus, 1014.
Scincidæ, 1142.
Scincus, 1142.
Sciuravus, 1420.
Sciuridæ, 1420.
Sciurodon, 1421.
Sciuroides, 1421.
Sciuromys, 1420.
Sciurus, 1421.
Scleroderma, 1015.
Sclerorhynchus, 931.
Scolopacidæ, 1232.
Scolopax, 1233.
Scomber, 1007.
Scomberodon, 1007.
Scombresocidæ, 1000.
Scombridæ, 1007.
Scombroclupea, 995.
Scopelidæ, 1001.
Scorpæna, 1012.
Scorpænidæ, 1012.
Scyllidæ, 943.
Scylliodus, 943.
Scyllium, 943.
Scymnus, 929.
Scytalophis, 1147.
Seeleya, 1027.
Selache, 946.
Selachei, 928.
Semionotus, 981.
Semiophorus, 1008.
Semnopithecus, 1470.
Serpentariidæ, 1239.
Serpentarius, 1239.

Serranus, 1013.
Sieboldia, 1041.
Sigmodus, 969.
Siluridæ, 1001.
Simædosauria, 1133.
Simædosaurus, 1133.
Simia, 1470.
Simiidæ, 1470.
Simocyon, 1433.
Simosaurus, 1072.
Simplicidentata, 1413.
Siphneus, 1417.
Siphonostoma, 1014.
Siredon, 1041.
Siren, 1041.
Sirenia, 1308.
Sirenidæ, 1041.
Sironectes, 1144.
Sitta, 1242.
Sittidæ, 1242.
Sivatherium, 1344.
Smerdis, 1013.
Smilerpeton, 1027.
Smilodon, 1449.
Sminthus, 1418.
Solea, 1004.
Solenacodon, 1268.
Solenognathus, 1005.
Solenorhynchus, 1014.
Solenostoma, 1014.
Solenostomatidæ, 1014.
Sorex, 1457.
Soricidæ, 1457.
Soricidens, 1013.
Spalacidæ, 1416.
Spalacodon, 1281.
Spalacotheriidæ, 1277.
Spalacotherium, 1277.
Spaniodon, 995.
Spaniotherium, 1331.
Sparidæ, 1012.
Sparnodus, 1012.
Sparodus, 1024.
Spathobatis, 933.
Spatula, 1237.
Speothos, 1436.
Spermophilus, 1420.
Sphærodontidæ, 986.
Sphærodus, 986, 1012.
Sphærolepis, 978.
Sphagebranchus, 1002.
Sphageopæa, 951.
Sphargis, 1091.
Sphenacanthus, 941.
Sphenocephalus, 1011.
Sphenodon, 1136.
Sphenodontidæ, 1136.
Sphenodontina, 1134.
Sphenodus, 945.
Sphenolepis, 1000.
Sphenosaurus, 1031.
Sphenospondylus, 1156.
Sphyræna, 1006.
Sphyrænidæ, 1006.
Sphyrænodus, 1007
Sphyrna, 946.
Spinacidæ, 929.
Spinax, 929.
Spondylosaurus, 1080.
Squalodon, 1306.
Squalodontidæ, 1306.
Squaloraia, 950.
Squaloraiidæ, 950.
Squamata, 1137.
Squamipennes, 1013.
Squatina, 931.
Squatinidæ, 930.
Stagonolepis, 1184.
Staurotypus, 1106.
Stegocephala, 1021.
Stegochelys, 1098.
Stegodon, 1395.
Steganopodes, 1238.
Stegosauridæ, 1161.
Stegosaurus, 1161.
Stemmatodus, 985.
Steneofiber, 1420.
Steneosaurus, 1187.
Steno, 1308.
Stenogale, 1445.
Stenopelix, 1164.
Stenoplesictis, 1439.
Stenostoma, 1012.
Stenotephanus, 1378.
Stephanodus, 1012.
Stereoceros, 1371.
Stereognathus, 1269.
Stereorhachis, 1060.
Stereospondyli, 1027.
Stereosternum, 1070.
Sternothærus, 1095.
Sthenurus, 1287.
Stichacanthus, 965.
Stratodus, 998.
Streblodus, 940.
Strepsiceros, 1348.
Strepsodus, 971.
Striges, 1240.
Strigidæ, 1241.
Strigilina, 929.
Stringopidæ, 1241.
Strix, 1241.
Strobilodus, 989.
Strophodus, 943.
Struthio, 1228.
Struthiolithus, 1228.
Struthiones, 1228.
Struthionidæ, 1228.
Struthiosaurus, 1163.
Stylacodon, 1276.
Stylemys, 1097, 1109.
Stylinodon, 1410.
Stylinodontidæ, 1410.
Stylodon, 1276.
Stylodontidæ, 981.
Stypolophus, 1452.
Sturnidæ, 1242.
Subungulata, 1312.
Suchosaurus, 1190.
Suidæ, 1318.
Sula, 1239.
Sus, 1319.

Syllæmus, 1005.
Syllophodus, 1416.
Symborodon, 1374.
Synætheres, 1415.
Synechodus, 943.
Syngnathidæ, 1014.
Syngnathus, 1014.
Syngonosaurus, 1161.
Systemodon, 1356.

Tæniura, 937.
Taligrada, 1385.
Talpa, 1457.
Talpavus, 1458.
Talpidæ, 1457.
Tamandua, 1295.
Tamias, 1421.
Taniwhasaurus, 1144.
Tanystrophæus, 1170.
Taphozous, 1462.
Taphrosphys, 1099.
Tapinocephalidæ, 1057.
Tapinocephalus, 1057, 1569.
Tapiridæ, 1354.
Tapirotherium, 1319.
Tapirulus, 1330.
Tapirus, 1354.
Tarrasiidæ, 968.
Tarrasius, 968.
Tatusia, 1292.
Taurinichthys,[1] 1004.
Taxeopoda, 1378.
Taxotherium, 1451.
Tectospondyli, 928.
Teiidæ, 1142.
Teleidosaurus, 1187
Teleosauridæ, 1186.
Teleosaurus, 1187.
Teleostei, 992.
Teleostomi, 902.
Telepholis, 1001.
Telerpetidæ, 1137.
Telerpeton, 1137.
Telmatolestes, 1466.
Telmatornis, 1229.
Tembotherium, 1377.
Temnocyon, 1436.
Temnodontosaurus, xi.
Temnospondyli, 1027.
Teracus, 1240.
Teratosaurus, 1167.
Testudinata, 1091.
Testudinidæ, 1107.
Testudo, 1109.
Tetrabelodon, 1395.
Tetraceros, 1347.
Tetraconodon, 1323.
Tetracus, 1457.
Tetragonolepis, 983.
Tetrao, 1234.
Tetraonidæ, 1234.
Tetrapturus, 1010.
Tetraselenodon, 1330.
Tetrastylus, 1415.
Tetrodon, 1015.
Tetrosphys, 1308.
Thalassemys, 1103.
Thalassictis, 1439.
Thalassochelys, 1114.
Thamnophis, 1146.
Thaumas, 931.
Thaumatacanthus, 947.
Thaumatosaurus, 1079.
Thecachampsa, 1194.
Thecodontosaurus, 1166.
Thecophora, 1091.
Thecospondylus, 1179.
Thelodus, 947.
Theosodon, 1376.
Therapon, 1013.
Theridomyidæ, 1415.
Theridomys, 1416.
Theriodesmus, 1269.
Theriodontia, 1057.
Theriognathus, 1064.
Theriosuchus, 1191.
Theromora, 1053.
Theromorpha, 1053.
Theropleura, 1060.
Theropoda, 1164.
Theuritherium, 1451, 1453.
Thinohyus, 1322.
Thinolestes, 1466.
Thinosaurus, 1139.
Thoatherium, 1359.
Thollodus, 986.
Thomomys, 1416.
Thoracophorus, 1294.
Thoracopterus, 987.
Thoracosaurus, 1193.
Thrissolepis, 978.
Thrissopater, 996.
Thrissops, 990.
Thursius, 971.
Thyestes, 962.
Thylacinus, 1278.
Thylacoleo, 1285.
Thylacomorphus, 1453.
Thynichthys, 1001.
Thynnus, 1007.
Thyrsites, 1010.
Tigrisuchus, 1059, 1569.
Tillodontia, 1408.
Tillomys, 1420.
Tillotherium, 1408.
Tinamus, 1232.
Tinca, 1000.
Tinoceras, 1388.
Tinosaurus, 1139.
Titanichthys, 965, 999.
Titanomys, 1413.
Titanophis, 1148.
Titanosaurus, 1179.
Titanosuchus, 1058.
Titanotheriidæ, 1374.
Titanotherium, 1374.
Tolypeutes, 1292.
Tomarctus, 1433.

[1] *Errore Saurinichthys.* See Corrigenda.

Tomistoma, 1193.
Tomitherium, 1466.
Tomodus, 940, 1378.
Tomognathus, 999.
Torpedinidæ, 934.
Torpedo, 934.
Totanus, 1233.
Toxochelys, 1104.
Toxodon, 1377.
Toxodontia, 1376.
Toxodontidæ, 1376.
Toxodontophanes, 1377.
Toxodontotherium, 1377.
Toxotes, 1013.
Trachinidæ, 1007.
Trachinopsis, 1007.
Trachinus, 1007.
Trachodon, 1153.
Trachodontidæ, 1153.
Trachyaspis, 1106.
Trachydermochelys, 1099.
Trachynotus, 1010.
Trachytherium, 1311.
Tragelaphus, 1348.
Tragoceros, 1349.
Tragulidæ, 1333.
Tragulus, 1333.
Trechomys, 1416.
Trematapis, 962.
Trematosaurus, 1036.
Tretosternum, 1105.
Triacanthodon, 1277.
Tribelesodon, 1204.
Tribodon, 1415.
Tribonyx, 1233.
Triceratops, 1163.
Trichechidæ, 1424.
Trichechodon, 1424.
Trichechus, 1424.
Trichiurichthys, 1010.
Trichiuridæ, 1010.
Trichiurus, 1010.
Triclis, 1287.
Triconodon, 1277.
Triconodontidæ, 1277.
Tricuspodon, 1288.
Trigla, 1006.
Triglyphus, 1269.
Trigodon, 1377.
Triisodon, 1453.
Trimerorhachidæ, 1029.
Trimerorhachis, 1032.
Trinacromeron, 1079.
Tringa, 1233.
Trionychidæ, 1117.
Trionychoidea, 1116.
Trionyx, 1118.
Triplopus, 1356.
Tripriodon, 1268.
Tristichopterus, 970.
Tristychius, 941.
Triton, 1041.
Tritylodon, 1269.
Tritylodontidæ, 1269.
Trochictis, 1427.
Troglodytes, 1470.
Trogon, 1242.
Trogonidæ, 1242.
Trogontherium, 1419.
Trogosus, 1408.
Tropidemys, 1104.
Tropidonotus, 1146.
Trucifelis, 1449.
Trygon, 937.
Trygonidæ, 937.
Trygonorhina, 933.
Tubinares, 1232.
Tuditanus, 1027.
Tupaia, 1455.
Tupaiidæ, 1455.
Tupinambis, 1142.
Tursiops, 1307.
Tylosaurus, 1144.
Typodus, 965.
Typotheriidæ, 1377.
Typotherium, 1377, 1378.
Typothorax, 1137, 1182.

Udenodon, 1064.
Uintacyon, 1437.
Uintatheriidæ, 1387.
Uintatherium, 1388.
Uintornis, 1242.
Undina, 973.
Ungulata, 1312.
Upupidæ, 1242.
Uria, 1232.
Urmiatherium, 1344.
Urocordylidæ, 1025.
Urocordylus, 1025.
Urolophus, 937.
Uronautes, 1082.
Urone nus, 955.
Urosphen, 1005.
Urosthenes, 978.
Ursidæ, 1430.
Ursus, 1431.

Vampyrus, 1463.
Varanidæ, 1141.
Varanus, 1141.
Vectisaurus, 1161.
Vespertiliavus, 1462.
Vespertilio, 1461.
Vespertilionidæ, 1461.
Vesperugo, 1461.
Viperidæ, 1148.
Vishnutherium, 1343.
Viverra, 1438.
Viverravus, 1437.
Viverridæ, 1437.
Vomer, 1009.
Vultur, 1239.

Wardia, 1569.
Wardichthys, 979.
Wodnika, 941.

Xenacanthus, 926.
Xenaspis, 961.
Xenorhynchus, 1238.
Xenurus, 1292.

Xeromys, 1417.
Xestops, 1141.
Xiphias, 1010.
Xiphiidæ, 1010.
Xiphodon, 1330.
Xiphodontotherium, 1330.
Xiphopteryx, 1010.
Xiphotrygon, 937.
Xystracanthus, 947.
Xystrodus, 940.

Zanclodon, 1167.
Zanclus, 1009.
Zapus, 1416.
Zarhachis, 1308.
Zatrhachys, 1032.
Zetodon, 1380.
Zeuglodon, 1304.
Zeuglodontidæ, 1304.
Zeus, 1007.
Ziphioides, 1305.
Ziphius, 1305.
Zooligus, 1331.
Zygæna, 946.
Zygobates, 936.
Zygomaturus, 1282.
Zygosaurus, 1031.

III.

INDEX TO PALÆOBOTANY.

Abies, 1537.
Abietinæ, 1536.
Acacia, 1556.
Acer, 1553.
Acetabularia, 1491.
Achras, 1557.
Acorus, 1542.
Actinostrobus, 1536.
Adiantites, 1504.
Adiantum, 1504.
Æsculinæ, 1552.
Æsculus, 1552.
Agavites, 1539.
Aggregatæ, 1558.
Ailanthus, 1552.
Albertia, 1534.
Alethopteridæ, 1509.
Alethopteris, 1504, 1509.
Algæ, 1488.
Alisma, 1543.
Alismaceæ, 1543.
Alnites, 1545.
Alnophyllum, 1545.
Alnus, 1545.
Alsophila, 1503.
Amelianchier, 1555.
Amentaceæ, 1544.
Amomocarpum, 1543.
Amomophyllum, 1543.
Amygdaleæ, 1555.
Amygdalus, 1555.
Amyris, 1552.
Anacardiaceæ, 1552.
Anacardites, 1552.
Anacardium, 1552.
Anchietea, 1550.
Andriana, 1510.
Andromeda, 1557.
Andromedites, 1557.
Aneimeites, 1506.
Angiopteridium, 1511.
Angiospermæ, 1538.
Annularia, 1516.
Anœctomeria, 1550.
Anomopteris, 1510.
Anomozamites, 1527.
Anona, 1550.
Anonaceæ, 1550.
Antholithus, 1530.
Apeiba, 1551.
Apeibopsis, 1551.
Apetalæ, 1544.
Apocyanaceæ, 1558.
Apocynophyllum, 1558.
Aquifoliaceæ, 1554.
Araceæ, 1542.
Aralia, 1554.
Araliaceæ, 1554.
Araucaria, 1533.
Araucarieæ, 1533.
Araucarioxylon, 1531.
Araucarites, 1533.
Arbutites, 1557.
Arbutus, 1557.
Archæocalamites, 1517.
Archæopterideæ, 1505.
Archæopteris, 1505.
Archagaricon, 1499.
Ardisia, 1557.
Aristolochia, 1557.
Aristolochiaceæ, 1556.
Aröides, 1539.
Aröites, 1542.
Aronites, 1542.
Arthropitys, 1516.
Arthrostigma, 1518.
Artiocarpidium, 1547.
Artiocarpoides, 1547.
Artisia, 1531.
Artocarpus, 1547.
Arundites, 1543.
Arundo, 1543.
Asimina, 1550.
Asperifoliaceæ, 1558.
Aspidieæ, 1505.
Aspidium, 1505.
Asplenieæ, 1504.
Asplenium, 1504.

Asterocalamites, 1516, 1517.
Asteroclæna, 1502.
Asterophyllites, 1516.
Asterophyllum, 1517.
Azalea, 1557.

Bactryllium, 1490.
Balanophoraceæ, 1557.
Bambusa, 1542.
Bambusium, 1539, 1543.
Banisteria, 1553.
Banksia, 1555.
Banksites, 1555.
Bauhinia, 1556.
Beania, 1528.
Belemnopteris, 1511.
Bennettites, 1528.
Bensonia, 1539.
Berberidaceæ, 1548.
Berberis, 1548.
Berchemia, 1554.
Betula, 1545.
Betulophyllum, 1545.
Bicornes, 1557.
Bidentites, 1559.
Bignonia, 1558.
Bignoniaceæ, 1558.
Bilobites, 1481.
Biota, 1536.
Bixaceæ, 1551.
Blechnum, 1504.
Bolbodium, 1528.
Bombaceæ, 1551.
Bombax, 1551.
Brachyphyllun, 1535.
Bromelia, 1540.
Bromeliaceæ, 1540.
Bryophyta, 1500.
Bucklandia, 1528.
Bumelia, 1557.
Buthotrephis, 1482.
Butomus, 1543.
Buxaceæ, 1554.

Cæsalpinia, 1556.
Cæsalpiniaceæ, 1556.
Cæsalpinites, 1556.
Calamiteæ, 1515.
Calamites, 1516.
Calamocladus, 1516.
Calamodendron, 1517.
Calamopsis, 1540.
Calamostachys, 1516.
Callipteridium, 1509.
Callipteris, 1509.
Callistemophyllum, 1555.
Callitris, 1536.
Callymatotheca, 1505.
Campanulinæ, 1558.
Camptophyllum, 1537.
Camptopteris, 1511.
Canna, 1543.
Cannophyllites, 1543.
Caprifoliaceæ, 1558.
Cardiocarpus, 1530.
Cardiopteris, 1508.
Carex, 1543.
Carpinus, 1545.
Carpolithes, 1550.
Carpolithus, 1530.
Carya, 1546.
Cassia, 1556.
Castanea, 1545.
Castanopsis, 1545.
Casuarina, 1544.
Casuarinidæ, 1544.
Catalpa, 1558.
Cauda Galli, 1483.
Caulinites, 1542.
Caulopteris, 1511.
Cedrus, 1537.
Celastraceæ, 1553.
Celastrinites, 1553.
Celastrophyllum, 1553.
Celastrus, 1553.
Celtis, 1547.
Centrospermæ, 1547.
Cephalotaxus, 1532.
Ceratonia, 1556.
Ceratophyleæ, 1547.
Ceratozamia, 1526.
Cercis, 1556.
Chamæcypris, 1536.
Chamærops, 1540.
Chara, 1498.
Characeæ, 1497.
Chilanthes, 1504.
Chirolepis, 1535.
Chiropteris, 1502.
Chlorosporeæ, 1491.
Chondrites, 1489.
Chondrophyllum, 1554.
Choripetalæ, 1544.
Choroniopteris, 1503.
Cinnamomum, 1548.
Cissites, 1554.
Cissus, 1554.
Cistaceæ, 1551.
Cistifloræ, 1550.
Cistus, 1551.
Cladophlebis, 1504.
Clathropodium, 1528.
Clathropteris, 1511.
Clematis, 1550.
Coccolabis, 1548.
Coccoliths, 1495.
Coccospheres, 1496.
Cocculus, 1548.
Cœlotrochium, 1493.
Columniferæ, 1551.
Colutea, 1556.
Combretaceæ, 1555.
Compositæ, 1558.
Coniferæ, 1531.
Coniopteris, 1503.
Convolvulus, 1558.
Contortæ, 1558.
Copaifera, 1556.
Corallina, 1495.
Corallineæ, 1495.
Cordaiteæ, 1529.

Cordaites, 1530.
Coriaria, 1552.
Coriariaceæ, 1552.
Cormophyta, 1500.
Cornaceæ, 1554.
Cornus, 1554.
Corylus, 1545.
Cotoneaster, 1556.
Cratægus, 1556.
Credneria, 1547.
Crematopteris, 1510.
Crossochorda, 1482.
Crossopodia, 1482.
Cruciferæ, 1550.
Ctenophyllum, 1527.
Ctenopteris, 1508.
Cunninghamia, 1534.
Cunninghamites, 1534.
Cupania, 1552.
Cupanites, 1552.
Cupanoides, 1552.
Cupressineæ, 1535.
Cupressus, 1536.
Cupuliferæ, 1544.
Cyathecaceæ, 1503.
Cyatheopteris, 1512.
Cyatholiths, 1496.
Cycadaceæ, 1525.
Cycadeæ, 1526.
Cycadeospermum, 1528.
Cycadites, 1526.
Cycadoidea, 1528.
Cycadopteris, 1510.
Cycadospadix, 1528.
Cycas, 1526.
Cyclanthaceæ, 1541.
Cyclopitys, 1534.
Cyclopteris, 1506.
Cyclostigma, 1521.
Cylindropodium, 1528.
Cymodocea, 1542.
Cymopolia, 1491, 1493.
Cyparissidium, 1535.
Cyperaceæ, 1543.
Cyperites, 1543.
Cyperus, 1543.
Cypselites, 1559.
Cytisus, 1556.
Czekanowskia, 1532.

Dactylopora, 1493, 1494.
Dactylopteris, 1512.
Dactylotheca, 1509.
Dadoxylon, 1531.
Dalbergia, 1556.
Dammara, 1533.
Dammarites, 1533.
Danæa, 1502.
Danæites, 1502.
Danæopsis, 1502.
Daphne, 1555.
Debea, 1550.
Delesseria, 1495.
Dewalquea, 1550.
Diatomaceæ, 1489.
Dichoneuron, 1539.
Dichopteris, 1510.
Dicksonia, 1503.
Dicotylæ, 1543.
Dicranophyllum, 1532.
Dictyocordaites, 1529.
Dictyophyllum, 1511.
Dictyopterideæ, 1511.
Dictyopteris, 1507.
Dictyozamites, 1527.
Didymosorus, 1503.
Dioscorea, 1539.
Dioscoreaceæ, 1539.
Dioscorites, 1539.
Diospyrineæ, 1557.
Diospyros, 1558.
Diplopora, 1491.
Dipterocarpeæ, 1551.
Dipterocarpus, 1551.
Discoliths, 1496.
Dodonæa, 1553.
Dombeyopsis, 1551.
Dracæna, 1539.
Drepanocarpus, 1556.
Dryandra, 1555.
Dryandroides, 1555.
Dryophyllum, 1545.

Ebenaceæ, 1557.
Echinostachys, 1539.
Echinostrobus, 1535.
Echitonium, 1558.
Elæocarpus, 1551.
Elatides, 1536.
Eleagnaceæ, 1555.
Eleagnus, 1555.
Embotheites, 1555.
Empetraceæ, 1554.
Enantioblastæ, 1540.
Encephalarteæ, 1526.
Encephalartos, 1526.
Engelhardtia, 1546.
Eopteris, 1485.
Ephedra, 1537.
Equisetaceæ, 1514.
Equisetæ, 1514.
Equisetites, 1514.
Equisetum, 1514.
Eremopteris, 1505.
Erica, 1557.
Ericaceæ, 1557.
Eriocaulon, 1540.
Ervites, 1556.
Erythina, 1556.
Ettingshausia, 1547.
Eucalyptus, 1555.
Euonomus, 1553.
Euphorbiaceæ, 1554.

Fagus, 1545.
Fasciculites, 1540.
Ficonium, 1547.
Ficus, 1547.
Fieldenia, 1532.
Filicaceæ, 1501.
Filices, 1502.
Filicites, 1503.

Fittonia, 1528.
Flabellaria, 1540.
Florideæ, 1495.
Forskohlea, 1547.
Forskohleanthemum, 1547.
Fracastella, 1551.
Frangulineæ, 1553.
Fraxinus, 1558.
Frenela, 1536.
Frenelopsis, 1536.
Freziera, 1551.
Fucaceæ, 1490.
Fungi, 1498.

Gamopetalæ, 1544.
Gangamopterideæ, 1511.
Gangamopteris, 1511.
Gardenia, 1558.
Gastrolobium, 1556.
Gaultheria, 1557.
Geinitzia, 1535.
Genista, 1556.
Gentianaceæ, 1558.
Geranium, 1551.
Ginkophyllum, 1529, 1531.
Gleditschia, 1556.
Gleichenia, 1503.
Gleicheniaceæ, 1503.
Gleichenites, 1503.
Glossopteris, 1511.
Glossozamites, 1526.
Glumifloræ, 1542.
Glyptodendron, 1483.
Glyptolepidium, 1534.
Glyptolepis, 1534.
Glyptostrobus, 1534.
Gnetaceæ, 1537.
Gnetum, 1537.
Goniolina, 1541.
Gramineæ, 1542.
Grevillea, 1551.
Grewia, 1551.
Grewiopsis, 1551.
Gruinales, 1551.
Guajacites, 1552.
Gymnospermæ, 1525.
Gynandræ, 1543.
Gyrogonites, 1498.
Gyroporella, 1493, 1494.

Haliserites, 1518.
Hallonia, 1520.
Halorhagidaceæ, 1555.
Hamamelidaceæ, 1554.
Hamamelites, 1554.
Hedera, 1554.
Helleborites, 1550.
Helleborus, 1550.
Hellobiæ, 1543.
Hepaticæ, 1501.
Heterophylleæ, 1556.
Heterosporeæ, 1518.
Hewardia, 1504.
Hieracites, 1559.
Hippocratea, 1554.
Hippocrateaceæ, 1554.

Hiræa, 1553.
Holopleura, 1550.
Hydrocharis, 1543.
Hydrocharitaceæ, 1543.
Hydrocharites, 1543.
Hymenæa, 1556.
Hymenophyllaceæ, 1503.
Hymenophyllum, 1503.
Hyoserites, 1559.

Ilex, 1554.
Indigofera, 1556.
Inga, 1556.
Inolepis, 1535.
Iridaceæ, 1539.
Iris, 1539.
Isoëteæ, 1521.
Isoëtes, 1521.
Isosporeæ, 1517.

Juglandaceæ, 1546.
Juglandites, 1546.
Juglans, 1546.
Juncaceæ, 1539.
Juncus, 1539.
Jungermanniaceæ, 1501.
Juniperus, 1536.

Kaidacarpum, 1541.
Kieselguhr, 1490.
Kiggelaria, 1551.
Knightia, 1555.
Knightites, 1555.
Knorria, 1520.
Kœlrueteria, 1552.

Labiatæfloræ, 1558.
Lacopteris, 1510.
Laharpia, 1543.
Laportea, 1547.
Larix, 1537.
Larvaria, 1493.
Lastræa, 1505.
Lauraceæ, 1548.
Laurus, 1548.
Leguminosæ, 1556.
Leguminosites, 1556.
Lemna, 1542.
Lemnophyllum, 1542.
Lepidodendreæ, 1520.
Lepidodendron, 1520.
Lepidophlœus, 1521.
Lepidopteris, 1510.
Lepidostrobus, 1520.
Leptomeria, 1557.
Leptophlœum, 1521.
Leptospermites, 1555.
Leptostrobus, 1534.
Leucothea, 1557.
Librocedrus, 1536.
Lichens, 1499.
Licrophycus, 1482.
Ligulatæ, 1518.
Liliaceæ, 1539.
Liliifloræ, 1539.
Linaceæ, 1552.

Linum, 1552.
Liquidambar, 1554.
Liriodendron, 1548.
Lithothamnion, 1496.
Litsæa, 1548.
Lomatia, 1535.
Lomatites, 1555.
Lomatophlœus, 1521.
Lomatopteridæ, 1510.
Lomatopteris, 1510.
Lonchopteris, 1509.
Lonicera, 1558.
Ludovica, 1541.
Ludoviopsis, 1541.
Lycopodiaceæ, 1517.
Lycopodieæ, 1518.
Lycopodites, 1518.
Lycopodium, 1518.
Lygodium, 1503.
Lythrariaceæ, 1555.

Macclintockia, 1547.
Macropterygium, 1527.
Macrostachya, 1516.
Macrotæniopteris, 1510.
Macrozamia, 1525.
Magnolia, 1548.
Magnoliaceæ, 1548.
Majanthemophyllum, 1539.
Malpighiaceæ, 1553.
Malpighiastrum, 1553.
Malvaceæ, 1551.
Mantellia, 1528.
Marantaceæ, 1543.
Marattia, 1502.
Marattiaceæ, 1502.
Marattiopsis, 1511.
Marchantia, 1501.
Mariopteris, 1509.
Marsilia, 1512.
Marsiliaceæ, 1512.
Marsilidium, 1512.
Marzaria, 1510.
Matonidium, 1510.
Maytenus, 1554.
Megaphyton, 1511.
Melastomaceæ, 1555.
Melastomites, 1555.
Melobesia, 1495.
Menispermaceæ, 1548.
Menispermites, 1548.
Merianopteris, 1510.
Mertensia, 1503.
Metrosideros, 1555.
Micropodium, 1556.
Mimosa, 1556.
Mimosaceæ, 1556.
Monocotylæ, 1538.
Moriconia, 1536.
Morus, 1547.
Musa, 1543.
Musaceæ, 1543.
Musaphyllum, 1543.
Musci, 1500.
Myrica, 1546.
Myricaceæ, 1546.
Myrsine, 1557.
Myrsiniaceæ, 1557.
Myrsinites, 1557.
Myrtaceæ, 1555.
Myrtifloræ, 1555.
Myrtophyllum, 1555.
Myrtus, 1555.

Naiadaceæ, 1542.
Naiadita, 1539.
Naias, 1542.
Nelumbium, 1550.
Nematodendreæ, 1484.
Nematophyton, 1484.
Neomeris, 1491.
Nephelium, 1552.
Nerium, 1558.
Neuropterideæ, 1506.
Neuropteridium, 1507.
Neuropteris, 1506.
Nilssonia, 1527.
Nipa, 1541.
Nipadites, 1541.
Nitella, 1498.
Nœggerathia, 1529.
Nœggerathieæ, 1529.
Nœggerathiopsis, 1528.
Nordenskiœldia, 1551.
Nostoc, 1490.
Notelœa, 1558.
Nullipores, 1496.
Nuphar, 1550.
Nymphœa, 1550.
Nymphœaceæ, 1550.
Nymphœites, 1550.
Nyssa, 1554.

Odontopterideæ, 1508.
Odontopteris, 1508.
Œthophyllum, 1539.
Olea, 1558.
Oleaceæ, 1558.
Oleandra, 1511.
Oleandridium, 1511.
Oligocarpia, 1505.
Onoclea, 1503.
Onychium, 1510.
Ophioglossaceæ, 1502.
Ophioglossum, 1502.
Opuntinæ, 1554.
Oreodaphne, 1548.
Osmunda, 1502.
Osmundaceæ, 1502.
Ostrya, 1545.
Osyris, 1557.
Otozamites, 1527.
Ottelia, 1543.
Ovulites, 1491, 1494.
Oxalidaceæ, 1551.
Oxalidites, 1551.
Oxylobium, 1556.

Pachyphyllum, 1533.
Pachypterideæ, 1510.
Pachypteris, 1510.
Pachytheca, 1483.

Pagiophyllum, 1533.
Palæanthus, 1559.
Palæocarya, 1546.
Palæochorda, 1482.
Palæocyparis, 1536.
Palæolobium, 1556.
Palæopterideæ, 1505.
Palæopteris, 1506, 1512.
Palæorchis, 1543.
Palæospathe, 1540.
Palæovittaria, 1511.
Palæoxyris, 1530.
Palissya, 1536.
Paliurus, 1554.
Palmaceæ, 1540.
Panax, 1554.
Pandanaceæ, 1541.
Pandanus, 1541.
Papaveraceæ, 1550.
Papilionaceæ, 1556.
Parrotia, 1554.
Parthenites, 1559.
Passiflorinæ, 1554.
Paullinia, 1552.
Pecopterideæ, 1509.
Pecopteris, 1509.
Pentaphylax, 1551.
Peronosporites, 1499.
Persea, 1548.
Persoonia, 1555.
Phanerogamæ, 1524.
Phascolites, 1556.
Phœnicites, 1540.
Phœnicopsis, 1532.
Phœnix, 1540.
Phragmites, 1543.
Phychochromophycæ, 1490.
Phylloglosseæ, 1518.
Phyllostrobus, 1536.
Phyllotheca, 1515.
Pilularia, 1512.
Pimelia, 1555.
Pinites, 1531.
Pinnularia, 1516.
Pinus, 1537.
Piper, 1557.
Piperineæ, 1547.
Piperites, 1547.
Pirus, 1555.
Piscidia, 1556.
Pistachia, 1552.
Pistia, 1542.
Pistites, 1542.
Pittosporaceæ, 1554.
Pittosporum, 1554.
Planera, 1543.
Platanaceæ, 1553.
Platanus, 1553.
Platylepis, 1528.
Podocarpus, 1532.
Podocarya, 1541.
Podogonium, 1556.
Podozamites, 1526.
Polirschiefer, 1490.
Polycarpieæ, 1548.
Polygonum, 1548.
Polypetalæ, 1544.
Polypodiaceæ, 1503.
Polypodieæ, 1504.
Polypodium, 1504.
Pomaceæ, 1555.
Populus, 1546.
Posidonia, 1542.
Potamogeton, 1542.
Pothocites, 1516, 1542.
Primulinæ, 1557.
Prosopis, 1556.
Protamyris, 1552.
Protannularia, 1514.
Proteaceæ, 1555.
Protoficus, 1547.
Protogens, 1480.
Protopteris, 1511.
Protorchis, 1543.
Protorhipis, 1511.
Protosalvinia, 1484, 1513.
Protostigma, 1483.
Prototaxites, 1484.
Prunus, 1555.
Psaronius, 1511.
Pseudophragmites, 1543.
Psilophyteæ, 1518.
Psilophyton, 1517.
Psiloteæ, 1518.
Psygmophyllum, 1529, 1531.
Ptelea, 1552.
Pterocarpus, 1556.
Pterocarya, 1546.
Pteridophyta, 1501.
Pteris, 1504.
Pterophyllum, 1527.
Pterospermites, 1551.
Ptilophyllum, 1527.
Ptilophyton, 1513.
Ptilozamites, 1527.
Ptychopteris, 1511.

Quercus, 1546.

Rafflesiaceæ, 1557.
Ranunculaceæ, 1550.
Ranunculus, 1550.
Renaultia, 1505.
Rhabdocarpus, 1530.
Rhachopteris, 1505.
Rhamnaceæ, 1554.
Rhamnites, 1554.
Rhamnus, 1554.
Rhipidopsis, 1532.
Rhiptozamites, 1527
Rhizocarpeæ, 1512.
Rhizocaulon, 1539.
Rhizomopteris, 1512.
Rhododendron, 1557.
Rhoëdinæ, 1550.
Rhus, 1552.
Robinia, 1556.
Rosa, 1555.
Rosaceæ, 1555.
Rosifloræ, 1555.
Rubiaceæ, 1558.
Rubiacites, 1558.

Rubiinæ, 1558.
Rutaceæ, 1552.

Sabal, 1540.
Sagenopteris, 1512.
Sagittaria, 1543.
Salicaceæ, 1546.
Salisburia, 1532.
Salix, 1546.
Salsola, 1548.
Salvinia, 1512.
Salviniaceæ, 1512.
Santalaceæ, 1557.
Santalum, 1557.
Sapindaceæ, 1552.
Sapindus, 1552.
Saportea, 1532.
Sapota, 1557.
Sapotaceæ, 1557.
Sapotites, 1557.
Sassafras, 1548.
Saururæ, 1551.
Saxifraginæ, 1554.
Scheuchzeria, 1543.
Schizeaceæ, 1502.
Schizoneura, 1514.
Schizoneureæ, 1514.
Sciadopitys, 1534.
Scirpus, 1543.
Scitamineæ, 1543.
Scleropteris, 1510.
Selaginella, 1519.
Selaginelleæ, 1519.
Sequoia, 1534.
Sigillareæ, 1521.
Sigillaria, 1521.
Silphidium, 1559.
Simarubaceæ, 1552.
Siphoneæ verticillatæ, 1491.
Smilacina, 1539.
Smilax, 1539.
Solanaceæ, 1558.
Solanites, 1558.
Spadicifloræ, 1540.
Sparganium, 1542.
Sphærococcites, 1495.
Sphagnum, 1500.
Sphallopteris, 1512.
Sphenophyllum, 1513.
Sphenopterideæ, 1505.
Sphenopteridium, 1505.
Sphenopteris, 1505.
Sphenothallus, 1483.
Sphenozamites, 1527.
Spirangium, 1538.
Spirophyton, 1483.
Sporangites, 1484, 1512.
Stachannularia, 1516.
Stachypteris, 1510.
Staphylea, 1553.
Stangerieæ, 1526.
Stenopteris, 1505.
Sterculia, 1551.
Sterculiaceæ, 1551.
Sternbergia, 1531.
Stichopteris, 1509.
Stigmaphyllum, 1553.
Stigmaria, 1520, 1522.
Stipulatæ, 1502.
Stratiotes, 1543.
Struthiopteris, 1503.
Stuartia, 1551.
Styracaceæ, 1558.
Styrax, 1558.
Sussea, 1541.
Swedenborgia, 1535.
Sympetalæ, 1557.
Symplocos, 1558.

Tabernæmontana, 1558.
Tæniopterideæ, 1510.
Tæniopteris, 1510.
Taxineæ, 1531.
Taxites, 1532.
Taxodineæ, 1534.
Taxodium, 1534.
Taxus, 1532.
Tephrosia, 1556.
Terebinthinæ, 1552.
Terminalia, 1555.
Ternstræmia, 1551.
Ternstræmiaceæ, 1551.
Tetrapteris, 1553.
Thamnopteris, 1512.
Thinnfeldia, 1510.
Thrysopteris, 1503.
Thuja, 1536.
Thujites, 1536.
Thujopsis, 1536.
Thymelaceæ, 1555.
Thymelinæ, 1555.
Tilia, 1551.
Tiliaceæ, 1551.
Torreya, 1532.
Trapa, 1555.
Trichopitys, 1532.
Tricoccæ, 1554.
Trigonella, 1556.
Trigonocarpus, 1523, 1530.
Trilobium, 1552.
Triphyllopteris, 1506.
Tripoli, 1490.
Trizygia, 1513.
Tubifloræ, 1558.
Tympanophora, 1503.
Typha, 1542.
Typhaceæ, 1542.
Typhæoloipum, 1542.

Ullmannia, 1533.
Ulmaceæ, 1547.
Ulmus, 1547.
Ulodendron, 1520, 1523.
Umbellifloræ, 1554.
Urnatopteris, 1505.
Urtica, 1547.
Urticaceæ, 1547.
Urticinæ, 1547.
Uteria, 1493, 1494.

Vacciniaceæ, 1557.
Vaccinium, 1557.

Valisneria, 1543.
Vertebraria, 1517.
Viburnum, 1558.
Victoria, 1550.
Violaceæ, 1550.
Vitaceæ, 1554.
Vitis, 1554.
Volkmannia, 1516.
Voltzia, 1534.

Walchia, 1532.
Walchieæ, 1532.
Wellingtonia, 1534.
Welwitschia, 1537.
Widdringtonia, 1536.
Widdringtonites, 1535.
Williamsonia, 1528, 1541.
Woodwardia, 1504.

Xanthidia, 1490.
Xanthoxylon, 1552.

Yucca, 1539.
Yuccites, 1539.

Zamieæ, 1526.
Zamiostrobus, 1528.
Zamites, 1526.
Zeilleria, 1505.
Zingiberaceæ, 1543.
Zingiberites, 1543.
Zizyphus, 1554.
Zostera, 1542.
Zosterites, 1542.
Zygophyllaceæ, 1552.

PRINTED BY WILLIAM BLACKWOOD AND SONS.

CATALOGUE

OF

MESSRS BLACKWOOD & SONS'

PUBLICATIONS.

PHILOSOPHICAL CLASSICS FOR ENGLISH READERS.

EDITED BY WILLIAM KNIGHT, LL.D.,
Professor of Moral Philosophy in the University of St Andrews.

In crown 8vo Volumes, with Portraits, price 3s. 6d.

Now ready—

1.	**Descartes.**	By Professor MAHAFFY, Dublin.
2.	**Butler.**	By Rev. W. LUCAS COLLINS, M.A.
3.	**Berkeley.**	By Professor CAMPBELL FRASER, Edinburgh.
4.	**Fichte.**	By Professor ADAMSON, Owens College, Manchester.
5.	**Kant.**	By Professor WALLACE, Oxford.
6.	**Hamilton.**	By Professor VEITCH, Glasgow.
7.	**Hegel.**	By Professor EDWARD CAIRD, Glasgow.
8.	**Leibniz.**	By J. THEODORE MERZ.
9.	**Vico.**	By Professor FLINT, Edinburgh.
10.	**Hobbes.**	By Professor CROOM ROBERTSON, London.
11.	**Hume.**	By the Editor.
12.	**Spinoza.**	By the Very Rev. Principal CAIRD, Glasgow.
13.	**Bacon.**	PART I.—The Life. By Professor NICHOL, Glasgow.
14.	**Bacon.**	PART II.—Philosophy. By the SAME AUTHOR.

In preparation.

Locke.	By Professor CAMPBELL FRASER, Edinburgh.
Mill.	By the Right Hon. A. J. BALFOUR.

FOREIGN CLASSICS FOR ENGLISH READERS.

EDITED BY MRS OLIPHANT.

In crown 8vo, 2s. 6d.

CONTENTS.

DANTE. By the Editor.
VOLTAIRE. By Lieut.-General Sir E. B. Hamley, K.C.B.
PASCAL. By Principal Tulloch.
PETRARCH. By Henry Reeve, C.B.
GOETHE. By A. Hayward, Q.C.
MOLIÈRE. By the Editor and F. Tarver, M.A.
MONTAIGNE. By Rev. W. L. Collins, M.A.
RABELAIS. By Walter Besant, M.A.
CALDERON. By E. J. Hasell.
SAINT SIMON. By Clifton W. Collins, M.A.
CERVANTES. By the Editor.
CORNEILLE AND RACINE. By Henry M. Trollope.
MADAME DE SÉVIGNÉ. By Miss Thackeray.
LA FONTAINE, AND OTHER FRENCH FABULISTS. By Rev. W. Lucas Collins, M.A.
SCHILLER. By James Sime, M.A., Author of 'Lessing: his Life and Writings.'
TASSO. By E. J. Hasell.
ROUSSEAU. By Henry Grey Graham.

NOW COMPLETE.

ANCIENT CLASSICS FOR ENGLISH READERS.

EDITED BY THE REV. W. LUCAS COLLINS, M.A.

Complete in 28 Vols. crown 8vo, cloth, price 2s. 6d. each. And may also be had in 14 Volumes, strongly and neatly bound, with calf or vellum back, £3, 10s.

Saturday Review.—"It is difficult to estimate too highly the value of such a series as this in giving 'English readers' an insight, exact as far as it goes, into those olden times which are so remote and yet to many of us so close."

CATALOGUE

OF

MESSRS BLACKWOOD & SONS'

PUBLICATIONS.

ALISON. History of Europe. By Sir ARCHIBALD ALISON, Bart., D.C.L.

1. From the Commencement of the French Revolution to the Battle of Waterloo.
 LIBRARY EDITION, 14 vols., with Portraits. Demy 8vo, £10, 10s.
 ANOTHER EDITION, in 20 vols. crown 8vo, £6.
 PEOPLE'S EDITION, 13 vols. crown 8vo, £2, 11s.
2. Continuation to the Accession of Louis Napoleon.
 LIBRARY EDITION, 8 vols. 8vo, £6, 7s. 6d.
 PEOPLE'S EDITION, 8 vols. crown 8vo, 34s.
3. Epitome of Alison's History of Europe. Twenty-ninth Thousand, 7s. 6d.
4. Atlas to Alison's History of Europe. By A. Keith Johnston.
 LIBRARY EDITION, demy 4to, £3, 3s.
 PEOPLE'S EDITION, 31s. 6d.

——— Life of John Duke of Marlborough. With some Account of his Contemporaries, and of the War of the Succession. Third Edition, 2 vols. 8vo. Portraits and Maps, 30s.

——— Essays: Historical, Political, and Miscellaneous. 3 vols. demy 8vo. 45s.

ACTA SANCTORUM HIBERNIÆ; Ex Codice Salmanticensi. Nunc primum integre edita opera CAROLI DE SMEDT et JOSEPHI DE BACKER, e Soc. Jesu, Hagiographorum Bollandianorum; Auctore et Sumptus Largiente JOANNE PATRICIO MARCHIONE BOTHAE. In One handsome 4to Volume, bound in half roxburghe, £2, 2s.; in paper wrapper, 31s. 6d.

AIRD. Poetical Works of Thomas Aird. Fifth Edition, with Memoir of the Author by the Rev. JARDINE WALLACE, and Portrait, Crown 8vo, 7s. 6d.

ALLARDYCE. The City of Sunshine. By ALEXANDER ALLARDYCE. Three vols. post 8vo, £1, 5s. 6d.

——— Memoir of the Honourable George Keith Elphinstone, K.B., Viscount Keith of Stonehaven, Marischal, Admiral of the Red. 8vo, with Portrait, Illustrations, and Maps, 21s.

ALMOND. Sermons by a Lay Head-master. By HELY HUTCHINSON ALMOND, M.A. Oxon., Head-master of Loretto School. Crown 8vo, 5s.

ANCIENT CLASSICS FOR ENGLISH READERS. Edited by Rev. W. Lucas Collins, M.A. Complete in 28 vols., cloth, 2s. 6d. each; or in 14 vols., tastefully bound, with calf or vellum back, £3, 10s.

Contents of the Series.

Homer: The Iliad, by the Editor.—Homer: The Odyssey, by the Editor.—Herodotus, by George C. Swayne, M.A.—Xenophon, by Sir Alexander Grant, Bart., LL.D.—Euripides, by W. B. Donne.—Aristophanes, by the Editor.—Plato, by Clifton W. Collins, M.A.—Lucian, by the Editor.—Æschylus, by the Right Rev. the Bishop of Colombo.—Sophocles, by Clifton W. Collins, M.A.—Hesiod and Theognis, by the Rev. J. Davies, M.A.—Greek Anthology, by Lord Neaves.—Virgil, by the Editor.—Horace, by Sir Theodore Martin, K.C.B.—Juvenal, by Edward Walford, M.A.—Plautus and Terence, by the Editor.—The Commentaries of Cæsar, by Anthony Trollope.—Tacitus, by W. B. Donne.—Cicero, by the Editor.—Pliny's Letters, by the Rev. Alfred Church, M.A., and the Rev. W. J. Brodribb, M.A.—Livy, by the Editor.—Ovid, by the Rev. A. Church, M.A.—Catullus, Tibullus, and Propertius, by the Rev. Jas. Davies, M.A.—Demosthenes, by the Rev. W. J. Brodribb, M.A.—Aristotle, by Sir Alexander Grant, Bart., LL.D.—Thucydides, by the Editor.—Lucretius, by W. H. Mallock, M.A.—Pindar, by the Rev. F. D. Morice, M.A.

AYTOUN. Lays of the Scottish Cavaliers, and other Poems. By W. Edmondstoune Aytoun, D.C.L., Professor of Rhetoric and Belles-Lettres in the University of Edinburgh. New Edition, printed from a new type, and tastefully bound. Fcap. 8vo, 3s. 6d.

Another Edition, being the Thirtieth. Fcap. 8vo, cloth extra, 7s. 6d.

Cheap Edition. Fcap. 8vo. Illustrated Cover. Price 1s.

——— An Illustrated Edition of the Lays of the Scottish Cavaliers. From designs by Sir Noel Paton. Small 4to, in gilt cloth, 21s.

——— Bothwell: a Poem. Third Edition. Fcap., 7s. 6d.

——— Poems and Ballads of Goethe. Translated by Professor Aytoun and Sir Theodore Martin, K.C.B. Third Edition. Fcap., 6s.

——— Bon Gaultier's Book of Ballads. By the Same. Fifteenth and Cheaper Edition. With Illustrations by Doyle, Leech, and Crowquill. Fcap. 8vo, 5s.

——— The Ballads of Scotland. Edited by Professor Aytoun. Fourth Edition. 2 vols. fcap. 8vo, 12s.

——— Memoir of William E. Aytoun, D.C.L. By Sir Theodore Martin, K.C.B. With Portrait. Post 8vo, 12s.

BACH. On Musical Education and Vocal Culture. By Albert B. Bach. Fourth Edition. 8vo, 7s. 6d.

——— The Principles of Singing. A Practical Guide for Vocalists and Teachers. With Course of Vocal Exercises. Crown 8vo, 6s.

——— The Art of Singing. With Musical Exercises for Young People. Crown 8vo, 3s.

BALLADS AND POEMS. By Members of the Glasgow Ballad Club. Crown 8vo, 7s. 6d

BANNATYNE. Handbook of Republican Institutions in the United States of America. Based upon Federal and State Laws, and other reliable sources of information. By Dugald J. Bannatyne, Scotch Solicitor, New York; Member of the Faculty of Procurators, Glasgow. Cr. 8vo, 7s. 6d.

BELLAIRS. The Transvaal War, 1880-81. Edited by Lady Bellairs. With a Frontispiece and Map. 8vo, 15s.

——— Gossips with Girls and Maidens, Betrothed and Free. New Edition. Crown 8vo, 5s.

BESANT. The Revolt of Man. By Walter Besant, M.A. Eighth Edition. Crown 8vo, 3s. 6d.

——— Readings in Rabelais. Crown 8vo, 7s. 6d.

BEVERIDGE. Culross and Tulliallan; or Perthshire on Forth. Its History and Antiquities. With Elucidations of Scottish Life and Character from the Burgh and Kirk-Session Records of that District. By David Beveridge. 2 vols. 8vo, with Illustrations, 42s.

——— Between the Ochils and the Forth; or, From Stirling Bridge to Aberdour. Crown 8vo, 6s.

BLACK. Heligoland and the Islands of the North Sea. By William George Black. Crown 8vo, 4s.

BLACKIE. Lays and Legends of Ancient Greece. By John Stuart Blackie, Emeritus Professor of Greek in the University of Edinburgh. Second Edition. Fcap. 8vo. 5s.

——— The Wisdom of Goethe. Fcap. 8vo. Cloth, extra gilt, 6s.

——— Scottish Song: Its Wealth, Wisdom, and Social Significance. Crown 8vo. With Music. 7s. 6d.

——— A Song of Heroes. Crown 8vo. [*In the press.*

BLACKWOOD'S MAGAZINE, from Commencement in 1817 to October 1889. Nos. 1 to 888, forming 144 Volumes.

——— Index to Blackwood's Magazine. Vols. 1 to 50. 8vo, 15s.

——— Tales from Blackwood. Forming Twelve Volumes of Interesting and Amusing Railway Reading. Price One Shilling each, in Paper Cover. Sold separately at all Railway Bookstalls.

They may also be had bound in cloth, 18s., and in half calf, richly gilt, 30s.

Or 12 volumes in 6, roxburghe, 21s., and half red morocco, 28s.

——— Tales from Blackwood. New Series. Complete in Twenty-four Shilling Parts. Handsomely bound in 12 vols., cloth, 30s. In leather back, roxburghe style, 37s. 6d. In half calf, gilt, 52s. 6d. In half morocco, 55s.

In course of Publication.

——— Tales from Blackwood. Third Series. In Parts. Each price 1s. [*Nos. I. to V. now ready.*

In course of Publication.

——— Travel, Adventure, and Sport. From 'Blackwood's Magazine.' In Parts. Uniform with 'Tales from Blackwood.' Each price 1s. [*Nos. I. to IV. now ready.*

——— Standard Novels. Uniform in size and legibly Printed. Each Novel complete in one volume.

FLORIN SERIES, Illustrated Boards. Or in New Cloth Binding, 2s. 6d.

Tom Cringle's Log. By Michael Scott.
The Cruise of the Midge. By the Same.
Cyril Thornton. By Captain Hamilton.
Annals of the Parish. By John Galt.
The Provost, &c. By John Galt.
Sir Andrew Wylie. By John Galt.
The Entail. By John Galt.
Miss Molly. By Beatrice May Butt.
Reginald Dalton. By J. G. Lockhart.
Pen Owen. By Dean Hook.
Adam Blair. By J. G. Lockhart.
Lady Lee's Widowhood. By General Sir E. B. Hamley.
Salem Chapel. By Mrs Oliphant.
The Perpetual Curate. By Mrs Oliphant.
Miss Marjoribanks. By Mrs Oliphant.
John: A Love Story. By Mrs Oliphant.

SHILLING SERIES, Illustrated Cover. Or in New Cloth Binding, 1s. 6d.

The Rector, and The Doctor's Family. By Mrs Oliphant.
The Life of Mansie Wauch. By D. M. Moir.
Peninsular Scenes and Sketches. By F. Hardman.
Sir Frizzle Pumpkin, Nights at Mess, &c.
The Subaltern.
Life in the Far West. By G. F. Ruxton.
Valerius: A Roman Story. By J. G. Lockhart.

BLACKMORE. The Maid of Sker. By R. D. Blackmore, Author of 'Lorna Doone,' &c. New Edition. Crown 8vo, 6s.

BLAIR. History of the Catholic Church of Scotland. From the Introduction of Christianity to the Present Day. By Alphons Bellesheim, D.D., Canon of Aix-la-Chapelle. Translated, with Notes and Additions, by D. Oswald Hunter Blair, O.S.B., Monk of Fort Augustus. To be completed in 4 vols. 8vo. Vols. I. and II. 25s. Vol. III. 12s. 6d.

BOSCOBEL TRACTS. Relating to the Escape of Charles the Second after the Battle of Worcester, and his subsequent Adventures. Edited by J. Hughes, Esq., A.M. A New Edition, with additional Notes and Illustrations, including Communications from the Rev. R. H. Barham, Author of the 'Ingoldsby Legends.' 8vo, with Engravings, 16s.

BROOKE, Life of Sir James, Rajah of Sarāwak. From his Personal Papers and Correspondence. By Spenser St John, H.M.'s Minister-Resident and Consul-General Peruvian Republic; formerly Secretary to the Rajah. With Portrait and a Map. Post 8vo, 12s. 6d.

BROUGHAM. Memoirs of the Life and Times of Henry Lord Brougham. Written by HIMSELF. 3 vols. 8vo, £2, 8s. The Volumes are sold separately, price 16s. each.

BROWN. The Forester: A Practical Treatise on the Planting, Rearing, and General Management of Forest-trees. By JAMES BROWN, LL.D., Inspector of and Reporter on Woods and Forests. Fifth Edition, revised and enlarged. Royal 8vo, with Engravings, 36s.

BROWN. The Ethics of George Eliot's Works. By JOHN CROMBIE BROWN. Fourth Edition. Crown 8vo, 2s. 6d.

BRYDALL. Art in Scotland; its Origin and Progress. By ROBERT BRYDALL, Master of St George's Art School of Glasgow. 8vo, 12s. 6d.

BROWN. A Manual of Botany, Anatomical and Physiological. For the Use of Students. By ROBERT BROWN, M.A., Ph.D. Crown 8vo, with numerous Illustrations, 12s. 6d.

BUCHAN. Introductory Text-Book of Meteorology. By ALEXANDER BUCHAN, M.A., F.R.S.E., Secretary of the Scottish Meteorological Society, &c. Crown 8vo, with 8 Coloured Charts and Engravings, 4s. 6d.

BUCHANAN. The Shirè Highlands (East Central Africa). By JOHN BUCHANAN, Planter at Zomba. Crown 8vo, 5s.

BURBIDGE. Domestic Floriculture, Window Gardening, and Floral Decorations. Being practical directions for the Propagation, Culture, and Arrangement of Plants and Flowers as Domestic Ornaments. By F. W. BURBIDGE. Second Edition. Crown 8vo, with numerous Illustrations, 7s. 6d.

——— Cultivated Plants: Their Propagation and Improvement. Including Natural and Artificial Hybridisation, Raising from Seed, Cuttings, and Layers, Grafting and Budding, as applied to the Families and Genera in Cultivation. Crown 8vo, with numerous Illustrations, 12s. 6d.

BURTON. The History of Scotland: From Agricola's Invasion to the Extinction of the last Jacobite Insurrection. By JOHN HILL BURTON, D.C.L., Historiographer-Royal for Scotland. New and Enlarged Edition, 8 vols., and Index. Crown 8vo, £3, 3s.

——— History of the British Empire during the Reign of Queen Anne. In 3 vols. 8vo. 36s.

——— The Scot Abroad. Third Edition. Crown 8vo, 10s. 6d.

——— The Book-Hunter. New Edition. With Portrait. Crown 8vo, 7s. 6d.

BUTE. The Roman Breviary: Reformed by Order of the Holy Œcumenical Council of Trent; Published by Order of Pope St Pius V.; and Revised by Clement VIII. and Urban VIII.; together with the Offices since granted. Translated out of Latin into English by JOHN, Marquess of Bute, K.T. In 2 vols, crown 8vo. cloth boards, edges uncut. £2, 2s.

——— The Altus of St Columba. With a Prose Paraphrase and Notes. In paper cover, 2s. 6d.

BUTLER. Pompeii: Descriptive and Picturesque. By W. BUTLER. Post 8vo, 5s.

BUTT. Miss Molly. By BEATRICE MAY BUTT. Cheap Edition, 2s.

——— Eugenie. Crown 8vo, 6s. 6d.

——— Elizabeth, and Other Sketches. Crown 8vo, 6s.

CAIRD. Sermons. By JOHN CAIRD, D.D., Principal of the University of Glasgow. Sixteenth Thousand. Fcap. 8vo, 5s.

——— Religion in Common Life. A Sermon preached in Crathie Church, October 14, 1855, before Her Majesty the Queen and Prince Albert. Published by Her Majesty's Command. Cheap Edition, 3d.

CAMPBELL. Sermons Preached before the Queen at Balmoral. By the Rev. A. A. CAMPBELL, Minister of Crathie. Published by Command of Her Majesty. Crown 8vo, 4s. 6d.

CAMPBELL. Records of Argyll. Legends, Traditions, and Recollections of Argyllshire Highlanders, collected chiefly from the Gaelic. With Notes on the Antiquity of the Dress, Clan Colours or Tartans of the Highlanders. By LORD ARCHIBALD CAMPBELL. Illustrated with Nineteen full-page Etchings. 4to, printed on hand-made paper, £3, 3s.

CANTON. A Lost Epic, and other Poems. By WILLIAM CANTON. Crown 8vo, 5s.

CARR. Margaret Maliphant. A Novel. By Mrs COMYNS CARR, Author of 'La Fortunina,' 'North Italian Folk,' &c. 3 vols. post 8vo, 25s. 6d.

CARRICK. Koumiss; or, Fermented Mare's Milk: and its Uses in the Treatment and Cure of Pulmonary Consumption, and other Wasting Diseases. With an Appendix on the best Methods of Fermenting Cow's Milk. By GEORGE L. CARRICK, M.D., L.R.C.S.E. and L.R.C.P.E., Physician to the British Embassy, St Petersburg, &c. Crown 8vo, 10s. 6d.

CAUVIN. A Treasury of the English and German Languages. Compiled from the best Authors and Lexicographers in both Languages. By JOSEPH CAUVIN, LL.D. and Ph.D., of the University of Göttingen, &c. Crown 8vo, 7s. 6d.

CAVE-BROWN. Lambeth Palace and its Associations. By J. CAVE-BROWN, M.A., Vicar of Detling, Kent, and for many years Curate of Lambeth Parish Church. With an Introduction by the Archbishop of Canterbury. Second Edition, containing an additional Chapter on Medieval Life in the Old Palaces. 8vo, with Illustrations, 21s.

CHARTERIS. Canonicity; or, Early Testimonies to the Existence and Use of the Books of the New Testament. Based on Kirchhoffer's 'Quellensammlung.' Edited by A. H. CHARTERIS, D.D., Professor of Biblical Criticism in the University of Edinburgh. 8vo, 18s.

CHRISTISON. Life of Sir Robert Christison, Bart., M.D., D.C.L. Oxon., Professor of Medical Jurisprudence in the University of Edinburgh. Edited by his SONS. In two vols. 8vo. Vol. I.—Autobiography. 16s. Vol. II. —Memoirs. 16s.

CHURCH SERVICE SOCIETY. A Book of Common Order: Being Forms of Worship issued by the Church Service Society. Fifth Edition. 6s.

CLELAND. Barbara Allan, the Provost's Daughter. By ROBERT CLELAND, Author of 'Inchbracken,' 'True to a Type,' &c. 2 vols., 17s.

CLOUSTON. Popular Tales and Fictions: their Migrations and Transformations. By W. A. CLOUSTON, Editor of 'Arabian Poetry for English Readers,' 'The Book of Sindibad,' &c. 2 vols. post 8vo, roxburghe binding, 25s.

COCHRAN. A Handy Text-Book of Military Law. Compiled chiefly to assist Officers preparing for Examination; also for all Officers of the Regular and Auxiliary Forces. Comprising also a Synopsis of part of the Army Act. By Major F. COCHRAN, Hampshire Regiment, Garrison Instructor. North British District. Crown 8vo, 7s. 6d.

COLQUHOUN. The Moor and the Loch. Containing Minute Instructions in all Highland Sports, with Wanderings over Crag and Corrie, Flood and Fell. By JOHN COLQUHOUN. Seventh Edition. With Illustrations. 8vo, 21s.

COTTERILL. Suggested Reforms in Public Schools. By C. C. COTTERILL, M.A., Assistant Master at Fettes College, Edin. Crown 8vo, 3s. 6d.

CRANSTOUN. The Elegies of Albius Tibullus. Translated into English Verse, with Life of the Poet, and Illustrative Notes. By JAMES CRANSTOUN, LL.D., Author of a Translation of 'Catullus.' Crown 8vo, 6s. 6d.

——— The Elegies of Sextus Propertius. Translated into English Verse, with Life of the Poet, and Illustrative Notes. Crown 8vo, 7s. 6d.

CRAWFORD. Saracinesca. By F. MARION CRAWFORD, Author of 'Mr Isaacs,' 'Dr Claudius,' 'Zoroaster,' &c. &c. Fourth Ed. Crown 8vo, 6s.

CRAWFORD. The Doctrine of Holy Scripture respecting the Atonement. By the late THOMAS J. CRAWFORD, D.D., Professor of Divinity in the University of Edinburgh. Fifth Edition. 8vo, 12s.

CRAWFORD. The Fatherhood of God, Considered in its General and Special Aspects, and particularly in relation to the Atonement, with a Review of Recent Speculations on the Subject. By the late THOMAS J. CRAWFORD, D.D., Professor of Divinity in the University of Edinburgh. Third Edition, Revised and Enlarged. 8vo, 9s.

——— The Preaching of the Cross, and other Sermons. 8vo, 7s. 6d.

——— The Mysteries of Christianity. Crown 8vo, 7s. 6d.

DAVIES. Norfolk Broads and Rivers; or, The Waterways, Lagoons, and Decoys of East Anglia. By G. CHRISTOPHER DAVIES, Author of 'The Swan and her Crew.' Illustrated with Seven full-page Plates. New and Cheaper Edition. Crown 8vo, 6s.

DAYNE. In the Name of the Tzar. A Novel. By J. BELFORD DAYNE. Crown 8vo, 6s.

——— Tribute to Satan. A Novel. Crown 8vo, 2s. 6d.

DE LA WARR. An Eastern Cruise in the 'Edeline.' By the Countess DE LA WARR. In Illustrated Cover. 2s.

DESCARTES. The Method, Meditations, and Principles of Philosophy of Descartes. Translated from the Original French and Latin. With a New Introductory Essay, Historical and Critical, on the Cartesian Philosophy. By JOHN VEITCH, LL.D., Professor of Logic and Rhetoric in the University of Glasgow. A New Edition, being the Ninth. Price 6s. 6d.

DICKSON. Gleanings from Japan. By W. G. DICKSON, Author of 'Japan: Being a Sketch of its History, Government, and Officers of the Empire.' With Illustrations. 8vo, 16s.

DOGS, OUR DOMESTICATED: Their Treatment in reference to Food, Diseases, Habits, Punishment, Accomplishments. By 'MAGENTA.' Crown 8vo, 2s. 6d.

DU CANE. The Odyssey of Homer, Books I.-XII. Translated into English Verse. By Sir CHARLES DU CANE, K.C.M.G. 8vo, 10s. 6d.

DUDGEON. History of the Edinburgh or Queen's Regiment Light Infantry Militia, now 3rd Battalion The Royal Scots; with an Account of the Origin and Progress of the Militia, and a Brief Sketch of the old Royal Scots. By Major R. C. DUDGEON, Adjutant 3rd Battalion The Royal Scots. Post 8vo, with Illustrations, 10s. 6d.

DUNCAN. Manual of the General Acts of Parliament relating to the Salmon Fisheries of Scotland from 1828 to 1882. By J. BARKER DUNCAN. Crown 8vo, 5s.

DUNSMORE. Manual of the Law of Scotland as to the Relations between Agricultural Tenants and their Landlords, Servants, Merchants, and Bowers. By W. DUNSMORE. 8vo, 7s. 6d.

DUPRÉ. Thoughts on Art, and Autobiographical Memoirs of Giovanni Dupré. Translated from the Italian by E. M. PERUZZI, with the permission of the Author. New Edition. With an Introduction by W. W. STORY. Crown 8vo, 10s. 6d.

ELIOT. George Eliot's Life, Related in her Letters and Journals. Arranged and Edited by her husband, J. W. CROSS. With Portrait and other Illustrations. Third Edition. 3 vols. post 8vo, 42s.

——— Works of George Eliot (Cabinet Edition). Handsomely printed in a new type, 21 volumes, crown 8vo, price £5, 5s. The Volumes are also sold separately, price 5s. each, viz.:—

Romola. 2 vols.—Silas Marner, The Lifted Veil, Brother Jacob. 1 vol.—Adam Bede. 2 vols.—Scenes of Clerical Life. 2 vols.—The Mill on the Floss. 2 vols.—Felix Holt. 2 vols.—Middlemarch. 3 vols.—Daniel Deronda. 3 vols.—The Spanish Gypsy. 1 vol.—Jubal, and other Poems, Old and New. 1 vol.—Theophrastus Such. 1 vol.—Essays. 1 vol.

——— George Eliot's Life. (Cabinet Edition.) With Portrait and other Illustrations. 3 vols. crown 8vo, 15s.

——— George Eliot's Life. With Portrait and other Illustrations. New Edition, in one volume. Crown 8vo, 7s. 6d.

ELIOT. Novels by GEORGE ELIOT. Cheap Edition. Adam Bede. Illustrated. 3s. 6d., cloth.—The Mill on the Floss. Illustrated. 3s. 6d., cloth.—Scenes of Clerical Life. Illustrated. 3s., cloth.—Silas Marner: The Weaver of Raveloe. Illustrated. 2s. 6d., cloth.—Felix Holt, the Radical. Illustrated. 3s. 6d., cloth.—Romola. With Vignette. 3s. 6d., cloth.

——— Middlemarch. Crown 8vo, 7s. 6d.

——— Daniel Deronda. Crown 8vo, 7s. 6d.

——— Essays. New Edition. Crown 8vo, 5s.

——— Impressions of Theophrastus Such. New Edition. Crown 8vo, 5s.

——— The Spanish Gypsy. New Edition. Crown 8vo, 5s.

——— The Legend of Jubal, and other Poems, Old and New. New Edition. Crown 8vo, 5s., cloth.

——— Wise, Witty, and Tender Sayings, in Prose and Verse. Selected from the Works of GEORGE ELIOT. Eighth Edition. Fcap. 8vo, 6s.

——— The George Eliot Birthday Book. Printed on fine paper, with red border, and handsomely bound in cloth, gilt. Fcap. 8vo, cloth, 3s. 6d. And in French morocco or Russia, 5s.

ESSAYS ON SOCIAL SUBJECTS. Originally published in the 'Saturday Review.' A New Edition. First and Second Series. 2 vols. crown 8vo, 6s. each.

EWALD. The Crown and its Advisers; or, Queen, Ministers, Lords, and Commons. By ALEXANDER CHARLES EWALD, F.S.A. Crown 8vo, 5s.

FAITHS OF THE WORLD, The. A Concise History of the Great Religious Systems of the World. By various Authors. Being the St Giles' Lectures—Second Series. Crown 8vo, 5s.

FARRER. A Tour in Greece in 1880. By RICHARD RIDLEY FARRER. With Twenty-seven full-page Illustrations by LORD WINDSOR. Royal 8vo, with a Map, 21s.

FERRIER. Philosophical Works of the late James F. Ferrier, B.A. Oxon., Professor of Moral Philosophy and Political Economy, St Andrews. New Edition. Edited by Sir ALEX. GRANT, Bart., D.C.L., and Professor LUSHINGTON. 3 vols. crown 8vo, 34s. 6d.

——— Institutes of Metaphysic. Third Edition. 10s. 6d.

——— Lectures on the Early Greek Philosophy. Third Edition, 10s. 6d.

——— Philosophical Remains, including the Lectures on Early Greek Philosophy. 2 vols., 24s.

FLETCHER. Lectures on the Opening Clauses of the Litany delivered in St Paul's Church, Edinburgh. By JOHN B. FLETCHER, M.A. Crown 8vo, 4s.

FLINT. The Philosophy of History in Europe. By ROBERT FLINT, D.D., LL.D., Professor of Divinity, University of Edinburgh. Vol. I. 8vo. [*New Edition in preparation.*

——— Theism. Being the Baird Lecture for 1876. By ROBERT FLINT, D.D., LL.D., Professor of Divinity, University of Edinburgh. Seventh Edition. Crown 8vo, 7s. 6d.

——— Anti-Theistic Theories. Being the Baird Lecture for 1877. Fourth Edition. Crown 8vo, 10s. 6d.

——— Agnosticism. Being the Croall Lectures for 1887-88. [*In the press.*

FORBES. Insulinde: Experiences of a Naturalist's Wife in the Eastern Archipelago. By Mrs H. O. FORBES. Post 8vo, with a Map. 8s. 6d.

FOREIGN CLASSICS FOR ENGLISH READERS. Edited by Mrs OLIPHANT. Price 2s. 6d. *For List of Volumes published, see page 2.*

FOTHERGILL. Diana Wentworth. By CAROLINE FOTHERGILL, Author of 'An Enthusiast,' &c. 3 vols. post 8vo, 25s. 6d.

FULLARTON. Merlin: A Dramatic Poem. By RALPH MACLEOD FULLARTON. Fcap. 8vo. *[Immediately.*

GALT. Annals of the Parish. By JOHN GALT. Fcap. 8vo, 2s.

——— The Provost. Fcap. 8vo, 2s.

——— Sir Andrew Wylie. Fcap. 8vo, 2s.

——— The Entail; or, The Laird of Grippy. Fcap. 8vo, 2s.

GENERAL ASSEMBLY OF THE CHURCH OF SCOTLAND.

——— Family Prayers. Authorised by the General Assembly of the Church of Scotland. A New Edition, crown 8vo, in large type, 4s. 6d. Another Edition, crown 8vo, 2s.

——— Prayers for Social and Family Worship. For the Use of Soldiers, Sailors, Colonists, and Sojourners in India, and other Persons, at home and abroad, who are deprived of the ordinary services of a Christian Ministry. Cheap Edition, 1s. 6d.

——— The Scottish Hymnal Appendix. 1. Longprimer type, 1s. 2. Nonpareil type, cloth limp, 4d.; paper cover, 2d.

——— Scottish Hymnal with Appendix Incorporated. Published for Use in Churches by Authority of the General Assembly. 1. Large type, cloth, red edges, 2s. 6d.; French morocco, 4s. 2. Bourgeois type, limp cloth, 1s.; French morocco, 2s. 3. Nonpareil type, cloth, red edges, 6d.; French morocco, 1s. 4d. 4. Paper covers, 3d. 5. Sunday-School Edition, paper covers, 1d. 6. Children's Hymnal, paper covers, 1d. No. 1, bound with the Psalms and Paraphrases, French morocco, 8s. No. 2, bound with the Psalms and Paraphrases, cloth, 2s.; French morocco, 3s.

GERARD. Reata: What's in a Name. By E. D. GERARD. New Edition. Crown 8vo, 6s.

——— Beggar my Neighbour. New Edition. Crown 8vo, 6s.

——— The Waters of Hercules. New Edition. Crown 8vo, 6s.

——— The Land beyond the Forest. Facts, Figures, and Fancies from Transylvania. By E. GERARD. In Two Volumes. With Maps and Illustrations. 25s.

GERARD. Stonyhurst Latin Grammar. By Rev. JOHN GERARD. Fcap. 8vo, 3s.

GILL. Free Trade: an Inquiry into the Nature of its Operation. By RICHARD GILL. Crown 8vo, 7s. 6d.

——— Free Trade under Protection. Crown 8vo, 7s. 6d.

GOETHE'S FAUST. Translated into English Verse by Sir THEODORE MARTIN, K.C.B. Part I. Second Edition, post 8vo, 6s. Ninth Edition, fcap., 3s. 6d. Part II. Second Edition, revised. Fcap. 8vo, 6s.

GOETHE. Poems and Ballads of Goethe. Translated by Professor AYTOUN and Sir THEODORE MARTIN, K.C.B. Third Edition, fcap. 8vo, 6s.

GOODALL. Juxta Crucem. Studies of the Love that is over us. By the late Rev. CHARLES GOODALL, B.D., Minister of Barr. With a Memoir by Rev. Dr Strong, Glasgow, and Portrait. Crown 8vo, 6s.

GORDON CUMMING. At Home in Fiji. By C. F. GORDON CUMMING, Author of 'From the Hebrides to the Himalayas.' Fourth Edition, post 8vo. With Illustrations and Map. 7s. 6d.

——— A Lady's Cruise in a French Man-of-War. New and Cheaper Edition. 8vo. With Illustrations and Map. 12s. 6d.

——— Fire-Fountains. The Kingdom of Hawaii: Its Volcanoes, and the History of its Missions. With Map and numerous Illustrations. 2 vols. 8vo, 25s.

——— Wanderings in China. New and Cheaper Edition. 8vo, with Illustrations, 10s.

——— Granite Crags: The Yō-semité Region of California. Illustrated with 8 Engravings. New and Cheaper Edition. 8vo, 8s. 6d.

GRAHAM. The Life and Work of Syed Ahmed Khan, C.S.I. By Lieut.-Colonel G. F. I. GRAHAM, B.S.C. 8vo, 14s.

GRANT. Bush-Life in Queensland. By A. C. GRANT. New Edition. Crown 8vo, 6s.

GRIFFITHS. Locked Up. By Major ARTHUR GRIFFITHS. Author of 'The Wrong Road,' 'Chronicles of Newgate,' &c. With Illustrations by C. J. STANILAND, R.I. Crown 8vo, 2s. 6d.

HAGGARD. Dodo and I. A Novel. By Captain ANDREW HAGGARD. Crown 8vo, 6s.

HALDANE. Subtropical Cultivations and Climates. A Handy Book for Planters, Colonists, and Settlers. By R. C. HALDANE. Post 8vo, 9s.

HALLETT. A Thousand Miles on an Elephant in the Shan States. By HOLT S. HALLETT, M. Inst. C.E., F.R.G.S., M.R.A.S., Hon. Member Manchester and Tyneside Geographical Societies. In 1 vol. 8vo, with Maps and numerous Illustrations. [*Immediately.*

HAMERTON. Wenderholme: A Story of Lancashire and Yorkshire Life. By PHILIP GILBERT HAMERTON, Author of 'A Painter's Camp.' A New Edition. Crown 8vo, 6s.

HAMILTON. Lectures on Metaphysics. By Sir WILLIAM HAMILTON, Bart., Professor of Logic and Metaphysics in the University of Edinburgh. Edited by the Rev. H. L. MANSEL, B.D., LL.D., Dean of St Paul's; and JOHN VEITCH, M.A., Professor of Logic and Rhetoric, Glasgow. Seventh Edition. 2 vols. 8vo, 24s.

——— Lectures on Logic. Edited by the SAME. Third Edition. 2 vols., 24s.

——— Discussions on Philosophy and Literature, Education and University Reform. Third Edition, 8vo, 21s.

——— Memoir of Sir William Hamilton, Bart., Professor of Logic and Metaphysics in the University of Edinburgh. By Professor VEITCH, of the University of Glasgow. 8vo, with Portrait, 18s.

——— Sir William Hamilton: The Man and his Philosophy. Two Lectures Delivered before the Edinburgh Philosophical Institution, January and February 1883. By the SAME. Crown 8vo, 2s.

HAMLEY. The Operations of War Explained and Illustrated. By Lieut.-General Sir EDWARD BRUCE HAMLEY, K.C.B., K.C.M.G., M.P. Fifth Edition, revised throughout. 4to, with numerous Illustrations, 30s.

——— National Defence; Articles and Speeches. Post 8vo, 6s.

——— Shakespeare's Funeral, and other Papers. Post 8vo, 7s. 6d.

——— Thomas Carlyle: An Essay. Second Edition. Crown 8vo. 2s. 6d.

——— The Story of the Campaign of Sebastopol. Written in the Camp. With Illustrations drawn in Camp by the Author. 8vo, 21s.

——— On Outposts. Second Edition. 8vo, 2s.

——— Wellington's Career; A Military and Political Summary. Crown 8vo, 2s.

——— Lady Lee's Widowhood. Crown 8vo, 2s. 6d.

——— Our Poor Relations. A Philozoic Essay. With Illustrations, chiefly by Ernest Griset. Crown 8vo, cloth gilt, 3s. 6d.

HAMLEY. Guilty, or Not Guilty? A Tale. By Major-General W. G. HAMLEY, late of the Royal Engineers. New Edition. Crown 8vo, 3s. 6d.

——— Traseaden Hall. "When George the Third was King." New and Cheaper Edition. Crown 8vo, 6s.

HARRISON. The Scot in Ulster. The Story of the Scottish Settlement in Ulster. By JOHN HARRISON, Author of 'Oure Tounis Colledge.' Crown 8vo, 2s. 6d.

HASELL. Bible Partings. By E. J. HASELL. Crown 8vo, 6s.

——— Short Family Prayers. Cloth, 1s.

HAY. The Works of the Right Rev. Dr George Hay, Bishop of Edinburgh. Edited under the Supervision of the Right Rev. Bishop STRAIN. With Memoir and Portrait of the Author. 5 vols. crown 8vo, bound in extra cloth, £1, 1s. Or, sold separately—viz.:

The Sincere Christian Instructed in the Faith of Christ from the Written Word. 2 vols., 8s.—The Devout Christian Instructed in the Law of Christ from the Written Word. 2 vols., 8s.—The Pious Christian Instructed in the Nature and Practice of the Principal Exercises of Piety. 1 vol., 4s.

HEATLEY. The Horse-Owner's Safeguard. A Handy Medical Guide for every Man who owns a Horse. By G. S. HEATLEY, M.R.C.V.S. Crown 8vo, 5s.

——— The Stock-Owner's Guide. A Handy Medical Treatise for every Man who owns an Ox or a Cow. Crown 8vo, 4s. 6d.

HEDDERWICK. Lays of Middle Age; and other Poems. By JAMES HEDDERWICK, LL.D. Price 3s. 6d.

HEMANS. The Poetical Works of Mrs Hemans. Copyright Editions.—One Volume, royal 8vo, 5s.—The Same, with Illustrations engraved on Steel, bound in cloth, gilt edges, 7s. 6d.—Six Volumes in Three, fcap., 12s. 6d.

SELECT POEMS OF MRS HEMANS. Fcap., cloth, gilt edges, 3s.

HOME PRAYERS. By Ministers of the Church of Scotland and Members of the Church Service Society. Second Edition. Fcap. 8vo, 3s.

HOMER. The Odyssey. Translated into English Verse in the Spenserian Stanza. By PHILIP STANHOPE WORSLEY. Third Edition, 2 vols. fcap., 12s.

——— The Iliad. Translated by P. S. WORSLEY and Professor CONINGTON. 2 vols. crown 8vo, 21s.

HOSACK. Mary Queen of Scots and Her Accusers. Containing a Variety of Documents never before published. By JOHN HOSACK, Barrister-at-Law. A New and Enlarged Edition, with a Photograph from the Bust on the Tomb in Westminster Abbey. 2 vols. 8vo, £1, 11s. 6d.

——— Mary Stewart. A Brief Statement of the Principal Charges which have been made against her, together with Answers to the same. Crown 8vo, 2s. 6d.

HUTCHINSON. Hints on the Game of Golf. By HORACE G. HUTCHINSON. Fourth Edition. Fcap. 8vo, cloth, 1s. 6d.

IDDESLEIGH. Lectures and Essays. By the late EARL OF IDDESLEIGH, G.C.B., D.C.L., &c. 8vo, 16s.

INDEX GEOGRAPHICUS: Being a List, alphabetically arranged, of the Principal Places on the Globe, with the Countries and Subdivisions of the Countries in which they are situated, and their Latitudes and Longitudes. Applicable to all Modern Atlases and Maps. Imperial 8vo, pp. 676, 21s.

JAMIESON. Discussions on the Atonement: Is it Vicarious? By the Rev. GEORGE JAMIESON, A.M., B.D., D.D., Author of 'Profound Problems in Philosophy and Theology.' 8vo, 16s.

JEAN JAMBON. Our Trip to Blunderland; or, Grand Excursion to Blundertown and Back. By JEAN JAMBON. With Sixty Illustrations designed by CHARLES DOYLE, engraved by DALZIEL. Fourth Thousand. Handsomely bound in cloth, gilt edges, 6s. 6d. Cheap Edition, cloth, 3s. 6d. In boards, 2s. 6d.

JENNINGS. Mr Gladstone: A Study. By LOUIS J. JENNINGS, M.P., Author of 'Republican Government in the United States,' 'The Croker Memoirs,' &c. Popular Edition. Crown 8vo, 1s.

JERNINGHAM. Reminiscences of an Attaché. By HUBERT E. H. JERNINGHAM. Second Edition. Crown 8vo, 5s.

——— Diane de Breteuille. A Love Story. Crown 8vo, 2s. 6d.

JOHNSTON. The Chemistry of Common Life. By Professor J. F. W. Johnston. New Edition, Revised, and brought down to date. By Arthur Herbert Church, M.A. Oxon.; Author of 'Food: its Sources, Constituents, and Uses,' &c., &c. Illustrated with Maps and 102 Engravings on Wood. Complete in one volume, crown 8vo, 7s. 6d.

——— Elements of Agricultural Chemistry and Geology. Revised, and brought down to date. By Sir Charles A. Cameron, M.D., F.R.C.S.I., &c. Fifteenth Edition. Fcap. 8vo, 6s. 6d.

——— Catechism of Agricultural Chemistry and Geology. An entirely New Edition, revised and enlarged, by Sir Charles A. Cameron, M.D., F.R.C.S.I.,&c. Eighty-sixth Thousand, with numerous Illustrations, 1s.

JOHNSTON. Patrick Hamilton: a Tragedy of the Reformation in Scotland, 1528. By T. P. Johnston. Crown 8vo, with Two Etchings. 5s.

KENNEDY. Sport, Travel, and Adventures in Newfoundland and the West Indies. By Captain W. R. Kennedy, R.N. With Illustrations by the Author. Post 8vo, 14s.

KER. Short Studies on St Paul's Letter to the Philippians. By Rev. William Lee Ker, Minister of Kilwinning. Crown 8vo, 5s.

KING. The Metamorphoses of Ovid. Translated in English Blank Verse. By Henry King, M.A., Fellow of Wadham College, Oxford, and of the Inner Temple, Barrister-at-Law. Crown 8vo, 10s. 6d.

KINGLAKE. History of the Invasion of the Crimea. By A. W. Kinglake. Cabinet Edition, revised. Illustrated with Maps and Plans. Complete in 9 Vols., crown 8vo, at 6s. each. The Volumes respectively contain:—I. The Origin of the War between the Czar and the Sultan. II. Russia Met and Invaded. III. The Battle of the Alma. IV. Sebastopol at Bay. V. The Battle of Balaclava. VI. The Battle of Inkerman. VII. Winter Troubles. VIII. and IX. From the Morrow of Inkerman to the Death of Lord Raglan. With an Index to the Complete Work.

——— History of the Invasion of the Crimea. Demy 8vo. Vol. VI. Winter Troubles. With a Map, 16s. Vols. VII. and VIII. From the Morrow of Inkerman to the Death of Lord Raglan. With an Index to the Whole Work. With Maps and Plans. 28s.

——— Eothen. A New Edition, uniform with the Cabinet Edition of the 'History of the Invasion of the Crimea,' price 6s.

KNOLLYS. The Elements of Field-Artillery. Designed for the Use of Infantry and Cavalry Officers. By Henry Knollys, Captain Royal Artillery; Author of 'From Sedan to Saarbrück,' Editor of 'Incidents in the Sepoy War,' &c. With Engravings. Crown 8vo, 7s. 6d.

LAVERGNE. The Rural Economy of England, Scotland, and Ireland. By Leonce de Lavergne. Translated from the French. With Notes by a Scottish Farmer. 8vo, 12s.

LAWLESS. Hurrish: a Study. By the Hon. Emily Lawless, Author of 'A Chelsea Householder,' 'A Millionaire's Cousin.' Fourth and cheaper Edition, crown 8vo. 6s.

LEE. A Phantom Lover: a Fantastic Story. By Vernon Lee. Crown 8vo, 1s.

LEE. Glimpses in the Twilight. Being various Notes, Records, and Examples of the Supernatural. By the Rev. George F. Lee, D.C.L. Crown 8vo. 8s. 6d.

LEES. A Handbook of Sheriff Court Styles. By J. M. Lees, M.A., LL.B., Advocate, Sheriff-Substitute of Lanarkshire. New Ed., 8vo, 21s.

——— A Handbook of the Sheriff and Justice of Peace Small Debt Courts. 8vo. 7s. 6d.

LETTERS FROM THE HIGHLANDS. Reprinted from 'The Times.' Fcap. 8vo, 4s. 6d.

LIGHTFOOT. Studies in Philosophy. By the Rev. J. Lightfoot, M.A., D.Sc., Vicar of Cross Stone, Todmorden. Crown 8vo, 4s. 6d.

LITTLE HAND AND MUCKLE GOLD. A Study of To-day. In 3 vols. post 8vo, 25s. 6d.

LOCKHART. Doubles and Quits. By LAURENCE W. M. LOCKHART. With Twelve Illustrations. Fourth Edition. Crown 8vo, 6s.

——— Fair to See: a Novel. Eighth Edition. Crown 8vo, 6s.

——— Mine is Thine: a Novel. Eighth Edition. Crown 8vo, 6s.

LORIMER. The Institutes of Law: A Treatise of the Principles of Jurisprudence as determined by Nature. By JAMES LORIMER, Regius Professor of Public Law and of the Law of Nature and Nations in the University of Edinburgh. New Edition, revised throughout, and much enlarged. 8vo, 18s.

——— The Institutes of the Law of Nations. A Treatise of the Jural Relation of Separate Political Communities. In 2 vols. 8vo. Volume I., price 16s. Volume II., price 20s.

LYSTER. Another Such Victory! By ANNETTE LYSTER, Author of 'A Leal Light Heart,' 'Two Old Maids,' 'Dr L'Estrange,' &c., &c. 3 vols. crown 8vo, 25s. 6d.

M'COMBIE. Cattle and Cattle-Breeders. By WILLIAM M'COMBIE, Tillyfour. New Edition, enlarged, with Memoir of the Author. By JAMES MACDONALD, of the 'Farming World.' Crown 8vo, 3s. 6d.

MACRAE. A Handbook of Deer-Stalking. By ALEXANDER MACRAE, late Forester to Lord Henry Bentinck. With Introduction by HORATIO ROSS, Esq. Fcap. 8vo, with two Photographs from Life. 3s. 6d.

M'CRIE. Works of the Rev. Thomas M'Crie, D.D. Uniform Edition. Four vols. crown 8vo, 24s.

——— Life of John Knox. Containing Illustrations of the History of the Reformation in Scotland. Crown 8vo, 6s. Another Edition, 3s. 6d.

——— Life of Andrew Melville. Containing Illustrations of the Ecclesiastical and Literary History of Scotland in the Sixteenth and Seventeenth Centuries. Crown 8vo, 6s.

——— History of the Progress and Suppression of the Reformation in Italy in the Sixteenth Century. Crown 8vo, 4s.

——— History of the Progress and Suppression of the Reformation in Spain in the Sixteenth Century. Crown 8vo, 3s. 6d.

——— Lectures on the Book of Esther. Fcap. 8vo, 5s.

MACDONALD. A Manual of the Criminal Law (Scotland) Procedure Act, 1887. By NORMAN DORAN MACDONALD. Revised by the LORD JUSTICE-CLERK. 8vo, cloth. 10s. 6d.

MACGREGOR. Life and Opinions of Major-General Sir Charles MacGregor, K.C.B., C.S.I., C.I.E., Quartermaster-General of India. From his Letters and Diaries. Edited by LADY MACGREGOR. With Portraits and Maps to illustrate Campaigns in which he was engaged. 2 vols. 8vo, 35s.

M'INTOSH. The Book of the Garden. By CHARLES M'INTOSH, formerly Curator of the Royal Gardens of his Majesty the King of the Belgians, and lately of those of his Grace the Duke of Buccleuch, K.G., at Dalkeith Palace. Two large vols. royal 8vo, embellished with 1350 Engravings. £4, 7s. 6d.

Vol. I. On the Formation of Gardens and Construction of Garden Edifices. 776 pages, and 1073 Engravings, £2, 10s.

Vol. II. Practical Gardening. 868 pages, and 279 Engravings, £1, 17s. 6d.

MACINTYRE. Hindu Koh: Wanderings and Wild Sports on and beyond the Himalayas. By Major-General DONALD MACINTYRE, V.C., late Prince of Wales' Own Goorkhas, F.R.G.S. *Dedicated to H.R.H. The Prince of Wales.* 8vo, with numerous Illustrations, 21s.

MACKAY. A Manual of Modern Geography; Mathematical, Physical, and Political. By the Rev. ALEXANDER MACKAY, LL.D., F.R.G.S. 11th Thousand, revised to the present time. Crown 8vo, pp. 688. 7s. 6d.

——— Elements of Modern Geography. 53d Thousand, revised to the present time. Crown 8vo, pp. 300, 3s.

——— The Intermediate Geography. By the Rev. ALEXANDER MACKAY, LL.D., F.R.G.S. Intended as an Intermediate Book between the Author's 'Outlines of Geography' and 'Elements of Geography.' Fifteenth Edition, revised. Crown 8vo, pp. 238, 2s.

MACKAY. Outlines of Modern Geography. 181st Thousand, revised to the present time. 18mo, pp. 118, 1s.

——— First Steps in Geography. 105th Thousand. 18mo, pp. 56. Sewed, 4d.; cloth, 6d.

——— Elements of Physiography and Physical Geography. With Express Reference to the Instructions recently issued by the Science and Art Department. 30th Thousand, revised. Crown 8vo, 1s. 6d.

——— Facts and Dates; or, the Leading Events in Sacred and Profane History, and the Principal Facts in the various Physical Sciences. The Memory being aided throughout by a Simple and Natural Method. For Schools and Private Reference. New Edition. Crown 8vo, 3s. 6d.

MACKAY. An Old Scots Brigade. Being the History of Mackay's Regiment, now incorporated with the Royal Scots. With an Appendix containing many Original Documents connected with the History of the Regiment. By JOHN MACKAY (late) OF HERRIESDALE. Crown 8vo, 5s.

MACKAY. The Founders of the American Republic. A History of Washington, Adams, Jefferson, Franklin, and Madison. With a Supplementary Chapter on the Inherent Causes of the Ultimate Failure of American Democracy. By CHARLES MACKAY, LL.D. Post 8vo, 10s. 6d.

MACKENZIE. Studies in Roman Law. With Comparative Views of the Laws of France, England, and Scotland. By LORD MACKENZIE, one of the Judges of the Court of Session in Scotland. Sixth Edition, Edited by JOHN KIRKPATRICK, Esq., M.A. Cantab.; Dr Jur. Heidelb.; LL.B. Edin. Advocate. 8vo, 12s.

MAIN. Three Hundred English Sonnets. Chosen and Edited by DAVID M. MAIN. Fcap. 8vo, 6s.

MAIR. A Digest of Laws and Decisions, Ecclesiastical and Civil, relating to the Constitution, Practice, and Affairs of the Church of Scotland. With Notes and Forms of Procedure. By the Rev. WILLIAM MAIR, D.D., Minister of the Parish of Earlston. Crown 8vo. With Supplements, 8s.

MARMORNE. The Story is told by ADOLPHUS SEGRAVE, the youngest of three Brothers. Third Edition. Crown 8vo, 6s.

MARSHALL. French Home Life. By FREDERIC MARSHALL. Second Edition. 5s.

MARSHMAN. History of India. From the Earliest Period to the Close of the India Company's Government; with an Epitome of Subsequent Events. By JOHN CLARK MARSHMAN, C.S.I. Abridged from the Author's larger work. Second Edition, revised. Crown 8vo, with Map, 6s. 6d.

MARTIN. Goethe's Faust. Part I. Translated by Sir THEODORE MARTIN, K.C.B. Second Ed., crown 8vo, 6s. Ninth Ed., fcap. 8vo, 3s. 6d.

——— Goethe's Faust. Part II. Translated into English Verse. Second Edition, revised. Fcap. 8vo, 6s.

——— The Works of Horace. Translated into English Verse, with Life and Notes. 2 vols. New Edition, crown 8vo, 21s.

——— Poems and Ballads of Heinrich Heine. Done into English Verse. Second Edition. Printed on *papier vergé*, crown 8vo, 8s.

——— The Song of the Bell, and other Translations from Schiller, Goethe, Uhland, and Others. Crown 8vo, 7s. 6d.

——— Catullus. With Life and Notes. Second Ed., post 8vo, 7s. 6d.

——— Aladdin: A Dramatic Poem. By ADAM OEHLENSCHLAEGER. Fcap. 8vo, 5s.

——— Correggio: A Tragedy. By OEHLENSCHLAEGER. With Notes. Fcap. 8vo, 3s.

——— King Rene's Daughter: A Danish Lyrical Drama. By HENRIK HERTZ. Second Edition, fcap., 2s. 6d.

MARTIN. On some of Shakespeare's Female Characters. In a Series of Letters. By HELENA FAUCIT, LADY MARTIN. Dedicated by permission to Her Most Gracious Majesty the Queen. Third Edition. 8vo, with Portrait, 7s 6d

MATHESON. Can the Old Faith Live with the New? or the Problem of Evolution and Revelation. By the Rev. GEORGE MATHESON, D.D. Third Edition. Crown 8vo, 7s. 6d.

——— The Psalmist and the Scientist; or, Modern Value of the Religious Sentiment. Crown 8vo, 7s. 6d.

MAURICE. The Balance of Military Power in Europe. An Examination of the War Resources of Great Britain and the Continental States. By Colonel MAURICE, R.A., Professor of Military Art and History at the Royal Staff College. Crown 8vo, with a Map. 6s.

MICHEL. A Critical Inquiry into the Scottish Language. With the view of Illustrating the Rise and Progress of Civilisation in Scotland. By FRANCISQUE-MICHEL, F.S.A. Lond. and Scot., Correspondant de l'Institut de France, &c. In One handsome Quarto Volume, printed on hand-made paper, and appropriately bound in Roxburghe style. Price 66s.

MICHIE. The Larch: Being a Practical Treatise on its Culture and General Management. By CHRISTOPHER Y. MICHIE, Forester, Cullen House. Crown 8vo, with Illustrations. New and Cheaper Edition, enlarged, 5s.

——— Practical Forestry. Crown 8vo, with Illustrations. 6s.

MIDDLETON. The Story of Alastair Bhan Comyn; or, The Tragedy of Dunphail. A Tale of Tradition and Romance. By the Lady MIDDLETON. Square 8vo, 10s.

MILNE. The Problem of the Churchless and Poor in our Large Towns. With special reference to the Home Mission Work of the Church of Scotland. By the Rev. ROBT. MILNE, M.A., D.D., Ardler. Crown 8vo, 3s. 6d.

MINTO. A Manual of English Prose Literature, Biographical and Critical: designed mainly to show Characteristics of Style. By W. MINTO, M.A., Professor of Logic in the University of Aberdeen. Third Edition, revised. Crown 8vo, 7s. 6d.

——— Characteristics of English Poets, from Chaucer to Shirley. New Edition, revised. Crown 8vo, 7s. 6d.

MITCHELL. Biographies of Eminent Soldiers of the last Four Centuries. By Major-General JOHN MITCHELL, Author of 'Life of Wallenstein.' With a Memoir of the Author. 8vo, 9s.

MOIR. Life of Mansie Wauch, Tailor in Dalkeith. With 8 Illustrations on Steel, by the late GEORGE CRUIKSHANK. Crown 8vo, 3s. 6d. Another Edition, fcap. 8vo, 1s. 6d.

MOMERIE. Defects of Modern Christianity, and other Sermons. By the Rev. A. W. MOMERIE, M.A., D.Sc., LL.D., Professor of Logic and Metaphysics in King's College, London. Third Edition. Crown 8vo, 5s.

——— The Basis of Religion. Being an Examination of Natural Religion. Second Edition. Crown 8vo, 2s. 6d.

——— The Origin of Evil, and other Sermons. Sixth Edition, enlarged. Crown 8vo, 5s.

——— Personality. The Beginning and End of Metaphysics, and a Necessary Assumption in all Positive Philosophy. Fourth Ed. Cr. 8vo, 3s.

——— Agnosticism. Second Edition, Revised. Crown 8vo, 5s.

——— Preaching and Hearing; and other Sermons. Second Edition. Crown 8vo, 4s. 6d.

——— Belief in God. Second Edition. Crown 8vo, 3s.

——— Inspiration; and other Sermons. Crown 8vo, 5s.

MONTAGUE. Campaigning in South Africa. Reminiscences of an Officer in 1879. By Captain W. E. MONTAGUE, 94th Regiment, Author of 'Claude Meadowleigh,' &c. 8vo, 10s. 6d.

MONTALEMBERT. Memoir of Count de Montalembert. A Chapter of Recent French History. By Mrs OLIPHANT, Author of the 'Life of Edward Irving,' &c. 2 vols. crown 8vo, £1, 4s.

MORISON. Sordello. An Outline Analysis of Mr Browning's Poem. By JEANIE MORISON, Author of 'The Purposes of the Ages,' 'Ane Booke of Ballades,' &c. Crown 8vo, 3s.

MURDOCH. Manual of the Law of Insolvency and Bankruptcy: Comprehending a Summary of the Law of Insolvency, Notour Bankruptcy, Composition-contracts, Trust-deeds, Cessios, and Sequestrations; and the Winding-up of Joint-Stock Companies in Scotland; with Annotations on the various Insolvency and Bankruptcy Statutes; and with Forms of Procedure applicable to these Subjects. By JAMES MURDOCH, Member of the Faculty of Procurators in Glasgow. Fifth Edition, Revised and Enlarged, 8vo, £1, 10s.

MY TRIVIAL LIFE AND MISFORTUNE: A Gossip with no Plot in Particular. By A PLAIN WOMAN. New Edition, crown 8vo, 6s.

By the SAME AUTHOR.

POOR NELLIE. New and Cheaper Edition. Crown 8vo, 6s.

NAPIER. The Construction of the Wonderful Canon of Logarithms (Mirifici Logarithmorum Canonis Constructio). By JOHN NAPIER of Merchiston. Translated for the first time, with Notes, and a Catalogue of Napier's Works, by WILLIAM RAE MACDONALD. Small 4to, 15s. *A few large paper copies may be had, printed on Whatman paper, price* 30s.

NEAVES. Songs and Verses, Social and Scientific. By an Old Contributor to 'Maga.' By the Hon. Lord NEAVES. Fifth Ed., fcap. 8vo, 4s.

——— The Greek Anthology. Being Vol. XX. of 'Ancient Classics for English Readers.' Crown 8vo, 2s. 6d.

NICHOLSON. A Manual of Zoology, for the Use of Students. With a General Introduction on the Principles of Zoology. By HENRY ALLEYNE NICHOLSON, M.D., D.Sc., F.L.S., F.G.S., Regius Professor of Natural History in the University of Aberdeen. Seventh Edition, rewritten and enlarged. Post 8vo, pp. 956, with 555 Engravings on Wood, 18s.

——— Text-Book of Zoology, for the Use of Schools. Fourth Edition, enlarged. Crown 8vo, with 188 Engravings on Wood, 7s. 6d.

——— Introductory Text-Book of Zoology, for the Use of Junior Classes. Sixth Edition, revised and enlarged, with 166 Engravings, 3s.

——— Outlines of Natural History, for Beginners; being Descriptions of a Progressive Series of Zoological Types. Third Edition, with Engravings, 1s. 6d.

——— A Manual of Palæontology, for the Use of Students. With a General Introduction on the Principles of Palæontology. Second Edition. Revised and greatly enlarged. 2 vols. 8vo, with 722 Engravings, £2, 2s.

——— The Ancient Life-History of the Earth. An Outline of the Principles and Leading Facts of Palæontological Science. Crown 8vo, with 276 Engravings, 10s. 6d.

——— On the "Tabulate Corals" of the Palæozoic Period, with Critical Descriptions of Illustrative Species. Illustrated with 15 Lithograph Plates and numerous Engravings. Super-royal 8vo, 21s.

——— Synopsis of the Classification of the Animal Kingdom. 8vo, with 106 Illustrations, 6s.

——— On the Structure and Affinities of the Genus Monticulipora and its Sub-Genera, with Critical Descriptions of Illustrative Species. Illustrated with numerous Engravings on wood and lithographed Plates. Super-royal 8vo, 18s.

NICHOLSON. Communion with Heaven, and other Sermons. By the late MAXWELL NICHOLSON, D.D., Minister of St Stephen's, Edinburgh. Crown 8vo, 5s. 6d.

——— Rest in Jesus. Sixth Edition. Fcap. 8vo, 4s. 6d.

NICHOLSON. A Treatise on Money, and Essays on Present Monetary Problems. By JOSEPH SHIELD NICHOLSON, M.A., D.Sc., Professor of Commercial and Political Economy and Mercantile Law in the University of Edinburgh. 8vo, 10s. 6d.

NICOLSON AND MURE. A Handbook to the Local Government (Scotland) Act, 1889. With Introduction, Explanatory Notes, and Index. By J. Badenach Nicolson, Advocate, Counsel to the Scotch Education Department, and W. J. Mure, Advocate, Legal Secretary to the Lord Advocate for Scotland. 8vo, 5s.

OLIPHANT. Masollam: a Problem of the Period. A Novel. By Laurence Oliphant. 3 vols. post 8vo, 25s. 6d.

——— Scientific Religion; or, Higher Possibilities of Life and Practice through the Operation of Natural Forces. Second Edition. 8vo, 16s.

——— Altiora Peto. New and Cheaper Edition. Crown 8vo, boards, 2s. 6d. Illustrated Edition. Crown 8vo, cloth, 6s.

——— Piccadilly: A Fragment of Contemporary Biography. With Eight Illustrations by Richard Doyle. Eighth Edition, 4s. 6d. Cheap Edition, in paper cover, 2s. 6d.

——— Traits and Travesties; Social and Political. Post 8vo, 10s. 6d.

——— The Land of Gilead. With Excursions in the Lebanon. With Illustrations and Maps. Demy 8vo, 21s.

——— The Land of Khemi. Post 8vo, with Illustrations, 10s. 6d.

——— Haifa: Life in Modern Palestine. 2d Edition. 8vo, 7s. 6d.

——— Episodes in a Life of Adventure; or, Moss from a Rolling Stone. Fourth Edition. Post 8vo, 6s.

——— Fashionable Philosophy, and other Sketches. In paper cover, 1s.

——— Sympneumata: or, Evolutionary Functions now Active in Man. Edited by Laurence Oliphant. Post 8vo, 10s. 6d.

OLIPHANT. Katie Stewart. By Mrs Oliphant. 2s. 6d.

OSBORN. Narratives of Voyage and Adventure. By Admiral Sherard Osborn, C.B. 3 vols. crown 8vo, 12s.

OSSIAN. The Poems of Ossian in the Original Gaelic. With a Literal Translation into English, and a Dissertation on the Authenticity of the Poems. By the Rev. Archibald Clerk. 2 vols. imperial 8vo, £1, 11s. 6d.

OSWALD. By Fell and Fjord; or, Scenes and Studies in Iceland. By E. J. Oswald. Post 8vo, with Illustrations. 7s. 6d.

OUTRAM. Lyrics: Legal and Miscellaneous. By the late George Outram, Esq., Advocate. New Edition, with Explanatory Notes. Edited by J. H. Stoddart, LL.D. and Illustrated by William Ralston and A. S. Boyd. Fcap. 8vo, 5s.

PAGE. Introductory Text-Book of Geology. By David Page, LL.D., Professor of Geology in the Durham University of Physical Science, Newcastle, and Professor Lapworth of Mason Science College, Birmingham. With Engravings and Glossarial Index. Twelfth Edition. Revised and Enlarged. 3s. 6d.

——— Advanced Text-Book of Geology, Descriptive and Industrial. With Engravings, and Glossary of Scientific Terms. Sixth Edition, revised and enlarged, 7s. 6d.

——— Introductory Text-Book of Physical Geography. With Sketch-Maps and Illustrations. Edited by Charles Lapworth, LL.D., F.G.S., &c., Professor of Geology and Mineralogy in the Mason Science College, Birmingham. 12th Edition. 2s. 6d.

——— Advanced Text-Book of Physical Geography. Third Edition, Revised and Enlarged by Prof. Lapworth. With Engravings. 5s.

PATON. Spindrift. By Sir J. Noel Paton. Fcap., cloth, 5s.

——— Poems by a Painter. Fcap., cloth, 5s.

PATON. Body and Soul. A Romance in Transcendental Pathology. By Frederick Noel Paton. Third Edition. Crown 8vo, 1s.

PATTERSON. Essays in History and Art. By R. Hogarth Patterson. 8vo, 12s.

——— The New Golden Age, and Influence of the Precious Metals upon the World. 2 vols. 8vo, 31s. 6d.

PAUL. History of the Royal Company of Archers, the Queen's Body-Guard for Scotland. By JAMES BALFOUR PAUL, Advocate of the Scottish Bar. Crown 4to, with Portraits and other Illustrations. £2, 2s.

PEILE. Lawn Tennis as a Game of Skill. With latest revised Laws as played by the Best Clubs. By Captain S. C. F. PEILE, B.S.C. Fourth Edition, fcap. cloth, 1s. 6d.

PETTIGREW. The Handy Book of Bees, and their Profitable Management. By A. PETTIGREW. Fifth Edition, Enlarged, with Engravings. Crown 8vo, 3s. 6d.

PHILOSOPHICAL CLASSICS FOR ENGLISH READERS. Companion Series to Ancient and Foreign Classics for English Readers Edited by WILLIAM KNIGHT, LL.D., Professor of Moral Philosophy, University of St Andrews. In crown 8vo volumes, with portraits, price 3s. 6d.

[*For list of Volumes published, see page 2.*

POLLOK. The Course of Time: A Poem. By ROBERT POLLOK, A.M. Small fcap. 8vo, cloth gilt, 2s. 6d. The Cottage Edition, 32mo, sewed, 8d. The Same, cloth, gilt edges, 1s. 6d. Another Edition, with Illustrations by Birket Foster and others, fcap., gilt cloth, 3s. 6d., or with edges gilt, 4s.

PORT ROYAL LOGIC. Translated from the French; with Introduction, Notes, and Appendix. By THOMAS SPENCER BAYNES, LL.D., Professor in the University of St Andrews. Tenth Edition, 12mo, 4s.

POTTS AND DARNELL. Aditus Faciliores: An easy Latin Construing Book, with Complete Vocabulary. By A. W. POTTS, M.A., LL.D., Head-Master of the Fettes College, Edinburgh; and the Rev. C. DARNELL, M.A., Head-Master of Cargilfield Preparatory School, Edinburgh. Tenth Edition, fcap. 8vo, 3s. 6d.

——— Aditus Faciliores Graeci. An easy Greek Construing Book, with Complete Vocabulary. Fourth Edition, fcap. 8vo, 3s.

PRINGLE. The Live-Stock of the Farm. By ROBERT O. PRINGLE. Third Edition. Revised and Edited by JAMES MACDONALD, of the 'Farming World,' &c. Crown 8vo, 7s. 6d.

PUBLIC GENERAL STATUTES AFFECTING SCOTLAND from 1707 to 1847, with Chronological Table and Index. 3 vols. large 8vo, £3, 3s.

PUBLIC GENERAL STATUTES AFFECTING SCOTLAND, COLLECTION OF. Published Annually with General Index.

RAMSAY. Rough Recollections of Military Service and Society. By Lieut.-Col. BALCARRES D. WARDLAW RAMSAY. Two vols. post 8vo, 21s.

RAMSAY. Scotland and Scotsmen in the Eighteenth Century. Edited from the MSS. of JOHN RAMSAY, Esq. of Ochtertyre, by ALEXANDER ALLARDYCE, Author of 'Memoir of Admiral Lord Keith, K.B.,' &c. 2 vols. 8vo, 31s. 6d.

RANKIN. A Handbook of the Church of Scotland. By JAMES RANKIN, D.D., Minister of Muthill; Author of 'Character Studies in the Old Testament,' &c. An entirely New and much Enlarged Edition. Crown 8vo, with 2 Maps, 7s. 6d.

RANKINE. A Treatise on the Rights and Burdens incident to the Ownership of Lands and other Heritages in Scotland. By JOHN RANKINE, M.A., Advocate, Professor of Scots Law in the University of Edinburgh. Second Edition, Revised and Enlarged. 8vo, 45s.

RECORDS OF THE TERCENTENARY FESTIVAL OF THE UNIVERSITY OF EDINBURGH. Celebrated in April 1884. Published under the Sanction of the Senatus Academicus. Large 4to, £2, 12s. 6d.

RICE. Reminiscences of Abraham Lincoln. By Distinguished Men of his Time. Collected and Edited by ALLEN THORNDIKE RICE, Editor of the 'North American Review.' Large 8vo, with Portraits, 21s.

ROBERTSON. Orellana, and other Poems. By J. LOGIE ROBERTSON, M.A. Fcap. 8vo. Printed on hand-made paper. 6s.

——— The White Angel of the Polly Ann, and other Stories. A Book of Fables and Fancies. Fcap. 8vo, 3s. 6d.

ROBERTSON. Our Holiday Among the Hills. By JAMES and JANET LOGIE ROBERTSON. Fcap. 8vo, 3s. 6d.

ROSCOE. Rambles with a Fishing-rod. By E. S. Roscoe. Crown 8vo, 4s. 6d.

ROSS. Old Scottish Regimental Colours. By Andrew Ross, S.S.C., Hon. Secretary Old Scottish Regimental Colours Committee. Dedicated by Special Permission to Her Majesty the Queen. Folio. £2, 12s. 6d.

RUSSELL. The Haigs of Bemersyde. A Family History. By John Russell. Large 8vo, with Illustrations. 21s.

RUSSELL. Fragments from Many Tables. Being the Recollections of some Wise and Witty Men and Women. By Geo. Russell. Cr. 8vo, 4s. 6d.

RUSSELL. Essays on Sacred Subjects for General Readers. By the Rev. William Russell, M.A. 8vo, 10s. 6d.

RUSTOW. The War for the Rhine Frontier, 1870. By Col. W. Rustow. Translated from the German, by John Layland Needham, Lieutenant R.M. Artillery. 3 vols. 8vo, with Maps and Plans, £1, 11s. 6d.

RUTLAND. Notes of an Irish Tour in 1846. By the Duke of Rutland, G.C.B. (Lord John Manners). New Edition. Crown 8vo, 2s. 6d.

RUTLAND. Gems of German Poetry. Translated by the Duchess of Rutland (Lady John Manners). Small quarto, 3s. 6d.

——— Impressions of Bad-Homburg. Comprising a Short Account of the Women's Associations of Germany under the Red Cross. Crown 8vo, 1s. 6d.

——— Some Personal Recollections of the Later Years of the Earl of Beaconsfield, K.G. Sixth Edition, 6d.

——— Employment of Women in the Public Service. 6d.

——— Some of the Advantages of Easily Accessible Reading and Recreation Rooms, and Free Libraries. With Remarks on Starting and Maintaining Them. Second Edition, crown 8vo, 1s.

——— A Sequel to Rich Men's Dwellings, and other Occasional Papers. Crown 8vo, 2s. 6d.

——— Encouraging Experiences of Reading and Recreation Rooms, Aims of Guilds, Nottingham Social Guild, Existing Institutions, &c., &c. Crown 8vo, 1s.

SCHILLER. Wallenstein. A Dramatic Poem. By Frederick von Schiller. Translated by C. G. A. Lockhart. Fcap. 8vo, 7s. 6d.

SCOTCH LOCH FISHING. By "Black Palmer." Crown 8vo, interleaved with blank pages, 4s.

SCOUGAL. Scenes from a Silent World; or, Prisons and their Inmates. By Francis Scougal. Crown 8vo, 6s.

SELLAR. Manual of the Education Acts for Scotland. By Alexander Craig Sellar, M.P. Eighth Edition. Revised and in great part rewritten by J. Edward Graham, B.A. Oxon., Advocate. Containing the Technical Schools Act, 1887, and all Acts bearing on Education in Scotland. With Rules for the conduct of Elections, with Notes and Cases. 8vo, 10s. 6d.

SELLER AND STEPHENS. Physiology at the Farm; in Aid of Rearing and Feeding the Live Stock. By William Seller, M.D., F.R.S.E., and Henry Stephens, F.R.S.E., Author of 'The Book of the Farm,' &c. Post 8vo, with Engravings, 16s.

SETH. Scottish Philosophy. A Comparison of the Scottish and German Answers to Hume. Balfour Philosophical Lectures, University of Edinburgh. By Andrew Seth, M.A., Professor of Logic, Rhetoric, and Metaphysics in the University of St Andrews. Crown 8vo, 5s.

——— Hegelianism and Personality. Balfour Philosophical Lectures. Second Series. Crown 8vo, 5s.

SETON. A Budget of Anecdotes. Chiefly relating to the Current Century. Compiled and Arranged by George Seton, Advocate, M.A. Oxon. New and Cheaper Edition, fcap. 8vo. Boards, 1s. 6d.

SHADWELL. The Life of Colin Campbell, Lord Clyde. Illustrated by Extracts from his Diary and Correspondence. By Lieutenant-General Shadwell, C.B. 2 vols. 8vo. With Portrait, Maps, and Plans. 36s.

SHAND. Half a Century; or, Changes in Men and Manners. By Alex. Innes Shand, Author of 'Against Time,' &c. Second Ed., 8vo, 12s. 6d.

——— Letters from the West of Ireland. Reprinted from the 'Times.' Crown 8vo, 5s.

SHARPE. Letters from and to Charles Kirkpatrick Sharpe. Edited by Alexander Allardyce, Author of 'Memoir of Admiral Lord Keith, K.B.,' &c. With a Memoir by the Rev. W. K. R. Bedford. In two vols. 8vo. Illustrated with Etchings and other Engravings. £2, 12s. 6d.

SIM. Margaret Sim's Cookery. With an Introduction by L. B. Walford, Author of 'Mr Smith: A Part of His Life,' &c. Crown 8vo, 5s.

SKELTON. Maitland of Lethington; and the Scotland of Mary Stuart. A History. By John Skelton, C.B., LL.D. Author of 'The Essays of Shirley.' Demy 8vo. 2 vols., 28s.

SMITH. Thorndale; or, The Conflict of Opinions. By William Smith, Author of 'A Discourse on Ethics,'&c. New Edition. Cr. 8vo, 10s. 6d.

——— Gravenhurst; or, Thoughts on Good and Evil. Second Edition, with Memoir of the Author. Crown 8vo, 8s.

——— The Story of William and Lucy Smith. Edited by George Merriam. Large post 8vo, 12s. 6d.

SMITH. Greek Testament Lessons for Colleges, Schools, and Private Students, consisting chiefly of the Sermon on the Mount and the Parables of our Lord. With Notes and Essays. By the Rev. J. Hunter Smith, M.A., King Edward's School, Birmingham. Crown 8vo 6s.

SMITH. Writings by the Way. By John Campbell Smith, M.A., Sheriff-Substitute. Crown 8vo, 9s.

SMITH. The Secretary for Scotland. Being a Statement of the Powers and Duties of the new Scottish Office. With a Short Historical Introduction and numerous references to important Administrative Documents. By W. C. Smith, LL.B., Advocate. 8vo, 6s.

SOLTERA. A Lady's Ride Across Spanish Honduras. By Maria Soltera. With Illustrations. Post 8vo, 12s. 6d.

SORLEY. The Ethics of Naturalism. Being the Shaw Fellowship Lectures, 1884. By W. R. Sorley, M.A., Fellow of Trinity College, Cambridge, and Examiner in Philosophy in the University of Edinburgh. Crown 8vo, 6s.

SPEEDY. Sport in the Highlands and Lowlands of Scotland with Rod and Gun. By Tom Speedy. Second Edition, Revised and Enlarged. With Illustrations by Lieut.-Gen. Hope Crealocke, C.B., C.M.G., and others. 8vo, 15s.

SPROTT. The Worship and Offices of the Church of Scotland. By George W. Sprott, D.D., Minister of North Berwick. Crown 8vo, 6s.

STAFFORD. How I Spent my Twentieth Year. Being a Record of a Tour Round the World, 1886-87. By the Marchioness of Stafford. With Illustrations. Third Edition, crown 8vo, 8s. 6d.

STARFORTH. Villa Residences and Farm Architecture: A Series of Designs. By John Starforth, Architect. 102 Engravings. Second Edition, medium 4to, £2, 17s. 6d.

STATISTICAL ACCOUNT OF SCOTLAND. Complete, with Index, 15 vols. 8vo, £16, 16s.

Each County sold separately, with Title, Index, and Map, neatly bound in cloth, forming a very valuable Manual to the Landowner, the Tenant, the Manufacturer, the Naturalist, the Tourist, &c.

STODDART. Angling Songs. By Thomas Tod Stoddart. New Edition, with a Memoir by Anna M. Stoddart. Crown 8vo, 7s. 6d.

STRICKLAND. Life of Agnes Strickland. By her Sister. Post 8vo, with Portrait engraved on Steel, 12s. 6d.

STURGIS. John-a-Dreams. A Tale. By Julian Sturgis. New Edition, crown 8vo, 3s. 6d.

——— Little Comedies, Old and New. Crown 8vo, 7s. 6d.

In course of publication.

STEPHENS' BOOK OF THE FARM; detailing the Labours of the Farmer, Farm-Steward, Ploughman, Shepherd, Hedger, Farm-Labourer, Field-Worker, and Cattleman. Illustrated with numerous Portraits of Animals and Engravings of Implements. Fourth Edition. Revised, and in great part rewritten by JAMES MACDONALD, of the 'Farming World,' &c., &c. Assisted by many of the leading agricultural authorities of the day. To be completed in Six Divisional Volumes.

[*Divisions I., II., and III., price* 10s. 6d. *each, now ready.*

——— The Book of Farm Buildings; their Arrangement and Construction. By HENRY STEPHENS, F.R.S.E., Author of 'The Book of the Farm;' and ROBERT SCOTT BURN. Illustrated with 1045 Plates and Engravings. Large 8vo, uniform with 'The Book of the Farm,' &c. £1, 11s. 6d.

——— The Book of Farm Implements and Machines. By J. SLIGHT and R. SCOTT BURN, Engineers. Edited by HENRY STEPHENS. Large 8vo, uniform with 'The Book of the Farm,' £2, 2s.

STEVENSON. British Fungi. (Hymenomycetes.) By Rev. JOHN STEVENSON, Author of 'Mycologia Scotia,' Hon. Sec. Cryptogamic Society of Scotland. 2 vols. post 8vo, with Illustrations, price 12s. 6d. each.
Vol. I. AGARICUS—BOLBITIUS. Vol. II. CORTINARIUS—DACRYMYCES.

STEWART. Advice to Purchasers of Horses. By JOHN STEWART, V.S., Author of 'Stable Economy.' New Edition. 2s. 6d.

——— Stable Economy. A Treatise on the Management of Horses in relation to Stabling, Grooming, Feeding, Watering, and Working. By JOHN STEWART, V.S. Seventh Edition, fcap. 8vo, 6s. 6d.

STORMONTH. Etymological and Pronouncing Dictionary of the English Language. Including a very Copious Selection of Scientific Terms. For Use in Schools and Colleges, and as a Book of General Reference. By the Rev. JAMES STORMONTH. The Pronunciation carefully Revised by the Rev. P. H. PHELP, M.A. Cantab. Tenth Edition, Revised throughout. Crown 8vo, pp. 800. 7s. 6d.

——— Dictionary of the English Language, Pronouncing, Etymological, and Explanatory. Revised by the Rev. P. H. PHELP. Library Edition. Imperial 8vo, handsomely bound in half morocco, 31s. 6d.

——— The School Etymological Dictionary and Word-Book. Fourth Edition. Fcap. 8vo, pp. 254. 2s.

STORY. Nero; A Historical Play. By W. W. STORY, Author of 'Roba di Roma.' Fcap. 8vo, 6s.

——— Vallombrosa. Post 8vo, 5s.

——— He and She; or, A Poet's Portfolio. Fcap. 3s. 6d.

——— Poems. 2 vols. fcap., 7s. 6d.

——— Fiammetta. A Summer Idyl. Crown 8vo, 7s. 6d.

SUTHERLAND. Handbook of Hardy Herbaceous and Alpine Flowers, for general Garden Decoration. Containing Descriptions of upwards of 1000 Species of Ornamental Hardy Perennial and Alpine Plants; along with Concise and Plain Instructions for their Propagation and Culture. By WILLIAM SUTHERLAND, Landscape Gardener; formerly Manager of the Herbaceous Department at Kew. Crown 8vo, 7s. 6d.

TAYLOR. The Story of My Life. By the late Colonel MEADOWS TAYLOR, Author of 'The Confessions of a Thug,' &c. &c. Edited by his Daughter. New and cheaper Edition, being the Fourth. Crown 8vo, 6s.

THOLUCK. Hours of Christian Devotion. Translated from the German of A. Tholuck, D.D., Professor of Theology in the University of Halle. By the Rev. ROBERT MENZIES, D.D. With a Preface written for this Translation by the Author. Second Edition, crown 8vo, 7s. 6d.

THOMSON. Handy Book of the Flower-Garden: being Practical Directions for the Propagation, Culture, and Arrangement of Plants in Flower-Gardens all the year round. With Engraved Plans, illustrative of the various systems of Grouping in Beds and Borders. By DAVID THOMSON, Gardener to his Grace the Duke of Buccleuch, K.T., at Drumlanrig. Fourth and Cheaper Edition, crown 8vo, 5s.

THOMSON. The Handy Book of Fruit-Culture under Glass: being a series of Elaborate Practical Treatises on the Cultivation and Forcing of Pines, Vines, Peaches, Figs, Melons, Strawberries, and Cucumbers. With Engravings of Hothouses, &c., most suitable for the Cultivation and Forcing of these Fruits. By DAVID THOMSON, Gardener to his Grace the Duke of Buccleuch, K.T., at Drumlanrig. Second Ed. Cr. 8vo, with Engravings, 7s. 6d.

THOMSON. A Practical Treatise on the Cultivation of the Grape-Vine. By WILLIAM THOMSON, Tweed Vineyards. Ninth Edition, 8vo, 5s.

THOMSON. Cookery for the Sick and Convalescent. With Directions for the Preparation of Poultices, Fomentations, &c. By BARBARA THOMSON. Fcap. 8vo, 1s. 6d.

THOTH. A Romance. Third Edition. Crown 8vo, 4s. 6d.

By the Same Author.

A DREAMER OF DREAMS. A Modern Romance. Second Edition. Crown 8vo, 6s.

TOM CRINGLE'S LOG. A New Edition, with Illustrations. Crown 8vo, cloth gilt, 5s. Cheap Edition, 2s.

TRANSACTIONS OF THE HIGHLAND AND AGRICULTURAL SOCIETY OF SCOTLAND. Published annually, price 5s.

TULLOCH. Rational Theology and Christian Philosophy in England in the Seventeenth Century. By JOHN TULLOCH, D.D., Principal of St Mary's College in the University of St Andrews; and one of her Majesty's Chaplains in Ordinary in Scotland. Second Edition. 2 vols. 8vo, 16s.

——— Modern Theories in Philosophy and Religion. 8vo, 15s.

——— Luther, and other Leaders of the Reformation. Third Edition, enlarged. Crown 8vo, 3s. 6d.

——— Memoir of Principal Tulloch, D.D., LL.D. By Mrs OLIPHANT, Author of 'Life of Edward Irving.' Third and Cheaper Edition. 8vo, with Portrait. 7s. 6d.

TWO STORIES OF THE SEEN AND THE UNSEEN. 'THE OPEN DOOR,' 'OLD LADY MARY.' Crown 8vo, cloth, 2s. 6d.

VEITCH. Institutes of Logic. By JOHN VEITCH, LL.D., Professor of Logic and Rhetoric in the University of Glasgow. Post 8vo, 12s. 6d.

——— The Feeling for Nature in Scottish Poetry. From the Earliest Times to the Present Day. 2 vols. fcap. 8vo, in roxburghe binding. 15s.

——— Merlin and Other Poems. Fcap. 8vo. 4s. 6d.

——— Knowing and Being. Essays in Philosophy. First Series. Crown 8vo, 5s.

VIRGIL. The Æneid of Virgil. Translated in English Blank Verse by G. K. RICKARDS, M.A., and Lord RAVENSWORTH. 2 vols. fcap. 8vo, 10s.

WALFORD. A Stiff-Necked Generation. By L. B. WALFORD, Author of 'Mr Smith: A Part of his Life,' &c. New and Cheaper Edition. In 1 vol. crown 8vo, 6s.

——— Four Biographies from 'Blackwood': Jane Taylor, Hannah More, Elizabeth Fry, Mary Somerville. Crown 8vo, 5s.

WARREN'S (SAMUEL) WORKS:—

Diary of a Late Physician. Cloth, 2s. 6d.; boards, 2s.

Ten Thousand A-Year. Cloth, 3s. 6d.; boards, 2s. 6d.

Now and Then. The Lily and the Bee. Intellectual and Moral Development of the Present Age. 4s. 6d

Essays: Critical, Imaginative, and Juridical. 5s.

WARREN. The Five Books of the Psalms. With Marginal Notes. By Rev. SAMUEL L. WARREN, Rector of Esher, Surrey; late Fellow, Dean, and Divinity Lecturer, Wadham College, Oxford. Crown 8vo, 5s.

WEBSTER. The Angler and the Loop-Rod. By DAVID WEBSTER. Crown 8vo, with Illustrations, 7s. 6d.

WELLINGTON. Wellington Prize Essays on "the System of Field Manœuvres best adapted for enabling our Troops to meet a Continental Army." Edited by Lieut.-General Sir EDWARD BRUCE HAMLEY, K.C.B. 8vo, 12s. 6d.

WENLEY. Socrates and Christ: A Study in the Philosophy of Religion. By R. M. WENLEY, M.A., Lecturer on Mental and Moral Philosophy in Queen Margaret College, Glasgow; Examiner in Philosophy in he University of Glasgow. Crown 8vo, 6s.

WERNER. A Visit to Stanley's Rear-Guard at Major Barttelot's Camp on the Aruhwimi. With an Account of River-Life on the Congo. By J. R. WERNER, F.R.G.S., Engineer, late in the Service of the Etat Independant du Congo. With Maps, Portraits and other Illustrations. 8vo. 16s.

WESTMINSTER ASSEMBLY. Minutes of the Westminster Assembly, while engaged in preparing their Directory for Church Government, Confession of Faith, and Catechisms (November 1644 to March 1649). Edited by the Rev. Professor ALEX. T. MITCHELL, of St Andrews, and the Rev. JOHN STRUTHERS, LL.D. With a Historical and Critical Introduction by Professor Mitchell. 8vo, 15s.

WHITE. The Eighteen Christian Centuries. By the Rev. JAMES WHITE. Seventh Edition, post 8vo, with Index, 6s.

——— History of France, from the Earliest Times. Sixth Thousand, post 8vo, with Index, 6s.

WHITE. Archæological Sketches in Scotland—Kintyre and Knapdale. By Colonel T. P. WHITE, R.E., of the Ordnance Survey. With numerous Illustrations. 2 vols. folio, £4, 4s. Vol. I., Kintyre, sold separately, £2, 2s.

——— The Ordnance Survey of the United Kingdom. A Popular Account. Crown 8vo, 5s.

WILLIAMSON. Poems of Nature and Life. By DAVID R. WILLIAMSON, Minister of Kirkmaiden. Fcap. 8vo, 3s.

WILLS AND GREENE. Drawing-room Dramas for Children. By W. G. WILLS and the Hon. Mrs GREENE. Crown 8vo, 6s.

WILSON. Works of Professor Wilson. Edited by his Son-in-Law Professor FERRIER. 12 vols. crown 8vo, £2, 8s.

——— Christopher in his Sporting-Jacket. 2 vols., 8s.

——— Isle of Palms, City of the Plague, and other Poems. 4s.

——— Lights and Shadows of Scottish Life, and other Tales. 4s.

——— Essays, Critical and Imaginative. 4 vols., 16s.

——— The Noctes Ambrosianæ. 4 vols., 16s.

——— Homer and his Translators, and the Greek Drama. Crown 8vo, 4s.

WINGATE. Annie Weir, and other Poems. By DAVID WINGATE. Fcap. 8vo, 5s.

——— Lily Neil. A Poem. Crown 8vo, 4s. 6d.

WORDSWORTH. The Historical Plays of Shakspeare. With Introductions and Notes. By CHARLES WORDSWORTH, D.C.L., Bishop of S. Andrews. 3 vols. post 8vo, each price 7s. 6d.

WORSLEY. Poems and Translations. By PHILIP STANHOPE WORSLEY, M.A. Edited by EDWARD WORSLEY. Second Edition, enlarged. Fcap. 8vo, 6s.

YATE. England and Russia Face to Face in Asia. A Record of Travel with the Afghan Boundary Commission. By Captain A. C. YATE, Bombay Staff Corps. 8vo, with Maps and Illustrations, 21s.

YATE. Northern Afghanistan; or, Letters from the Afghan Boundary Commission. By Major C. E. Yate, C.S.I., C.M.G. Bombay Staff Corps, F.R.G.S. 8vo, with Maps. 18s.

YOUNG. A Story of Active Service in Foreign Lands. Compiled from letters sent home from South Africa, India, and China, 1856-1882. By Surgeon-General A. Graham Young, Author of 'Crimean Cracks.' Crown 8vo, Illustrated, 7s. 6d.

YULE. Fortification: for the Use of Officers in the Army, and Readers of Military History. By Col. YULE, Bengal Engineers. 8vo, with numerous Illustrations, 10s. 6d.